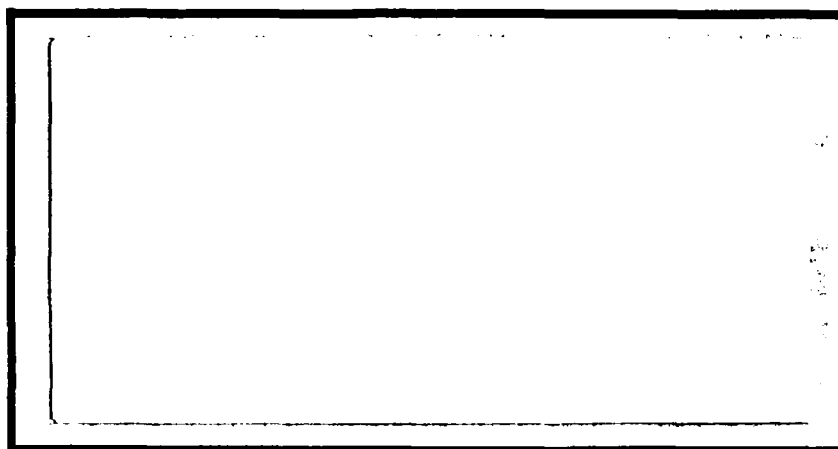


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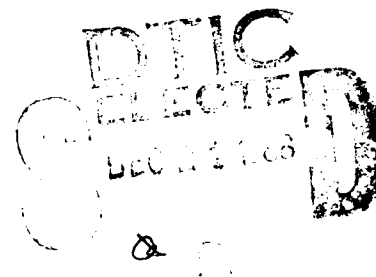
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DEVELOPING CRITERIA FOR SAMPLE SIZES
IN JET ENGINE ANALYTICAL COMPONENT
INSPECTIONS AND THE ASSOCIATED
CONFIDENCE LEVELS

THESIS

Tami S. Richards
Captain, USAF

AFIT/GSM/LSM/88S-22



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Presented to the Faculty of the School of Systems and
Logistics of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Systems Management

Tami S. Richards
Captain, USAF

September 1988

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Preface

The purpose of this study was to provide managers of USAF jet engine programs with a model to help determine an appropriate sample size of engines/components to be inspected in a Lead-the-Force/Analytical Component Inspection program. The need for this model was most recently experienced in the F110-GE-100 engine program at ASD. That office was instrumental in providing data and assistance to me for which I am deeply grateful. I hope the results of this study will in return help make their job easier.

I owe a great deal of thanks to my thesis advisor, Major Phillip Miller, who patiently answered my questions and gently guided me toward significant improvements in the quality of my thesis. I would also like to acknowledge and thank Professor Daniel Reynolds of AFIT who helped me with the initial statistics and Dr. Donald Marx of the University of Alaska for providing me with a computer program that substantially reduced my workload. His willingness to help an unseen student was truly appreciated. Finally, I wish to thank my husband, Chuck, for his understanding, help, and support throughout this thesis process.

Tami S. Richards

Table of Contents

	Page
Preface	ii
List of Figures	v
List of Tables	vi
Abstract	vii
I. Introduction	1
General Issue	1
Problem Statement	2
Research Objectives	2
Scope	3
Limitations	3
Assumptions	4
II. Methodology	5
Overview	5
Population	5
Sample	6
Justification for Assuming a Random Sample	7
Data Collection	9
Definitions	9
Developing the Model	9
Statistical Analysis	10
Computer Program	12
III. Literature Review	14
Introduction	14
Topic Statement	14
Justification	14
Plan of Development	15
Analysis of the Literature	15
Purpose	15
Key Participants	16
Guidelines	16
ACIs	17
Past and Current LTF/ACI Programs	19
Problems Faced in an ACI Program	22
Components Inspected in an ACI Program	24
Summary	26

	Page
IV. Findings and Analysis	28
Statistics	28
Binomial Probability	
Distribution.	28
Statistics Definitions	31
Assumptions.	34
Exact Confidence Bounds for	
Proportions Program.	36
Program Modification	37
Modified Program Limitations	39
Data Analysis.	39
Trends	41
Summary Graphs	51
V. Recommendations and Conclusions.	52
Implications as a Management Tool. . .	52
Practical Application	57
Recommendations for Follow-On Study. .	59
Appendix A: Pearson and Hartley Charts	62
Appendix B: Data Tables for $E=+/- .1$, $E=+/- .15$, and $E=+/- .175$	64
Appendix C: Proportion Graphs	98
Appendix D: Marx Computer Program and Modified Computer Program	107
Bibliography	117
Vita	119

List of Figures

Figure	Page
1. Example Graph.	11
2. $P = .8$	43
3. $E = +/-.1$ $P = 1.00$ $N = 400$	44
4. $E = +/-.1$ $P = 1.00$ $N = 50$	45
5. $E = +/-.15$ $P = 1.00$ $N = 400$	45
6. $E = +/-.15$ $P = 1.00$ $N = 50$	46
7. $E = +/-.175$ $P = 1.00$ $N = 400$	46
8. $E = +/-.175$ $P = 1.00$ $N = 50$	47
9. $E = +/-.1$ $P = 1.00$ $N = 30$	47
10. $E = +/-.15$ $P = 1.00$ $N = 30$	48
11. $E = +/-.175$ $P = 1.00$ $N = 30$	48
12. $P = .75$	50
13. $P = .6666667$	50
14. Summary Graph $P = 1.00$	54
15. Summary Graph $.95 \leq P < 1.00$	54
16. Summary Graph $.9 \leq P < .95$	55
17. Summary Graph $.85 \leq P < .9$	55
18. Summary Graph $.8 \leq P < .85$	56
19. Summary Graph $.7 \leq P < .8$	56

List of Tables

Table		Page
I.	F100-PW-100 Experience on Several ACI Components	20
II.	F110-GE-100 Controls and Accessories Addressed in ACI Program	25
III.	Data Table Excerpt	41

Abstract

The purpose of this study was to provide managers of USAF jet engine programs with a model to help determine an appropriate sample size of engines/components to be inspected in a Lead-the-Force/Analytical Component Inspection (LTF/ACI) program. The major purpose of a LTF/ACI program is to identify problems and failure trends in engines/components before the problems are experienced by the majority of the fleet. The concept behind the LTF/ACI program is that a sample of engines with accelerated operating hours can represent the future status of the entire fleet. Initial engine/component inspection intervals for the fleet are set low and extended as the LTF/ACI engines/components pass inspection criteria.

The study has two specific objectives: (1) to determine what sample size of components is required to reach some specific level of confidence that the inspection interval for the fleet can be increased, (i.e., the fleet can continue flying past that initial interval safely); (2) to determine the risk or decrease in confidence that is associated with a less-than-optimum sample size.

Small sample binomial statistics were used for the analysis due to the small number of engines/components usually inspected in an LTF/ACI program and the pass/fail nature of the inspection plan.

The study found that the increase (decrease) in confidence attained by varying the sample size of engines/components slightly is significant enough to warrant careful consideration by managers attempting to balance cost, logistical, and engineering constraints. The study provides data tables and graphs presenting the required sample sizes to ensure varying confidence levels for varying levels of an acceptable number of components/engines that pass inspection within specified error limits.

DEVELOPING CRITERIA FOR SAMPLE SIZES
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Introduction

General Issue

When a new AF jet engine goes operational, a Lead-The-Force inspection program is initiated. A Lead-The-Force (LTF) program designates a specific number of flight hours per month to gain an inspection interval lead over the rest of the fleet. The purpose of a LTF program is to gain early intelligence on engine integrity, reliability, and maintainability. Most importantly, the program is designed to identify potential premature engine component failures.

The inspection intervals in the LTF program are set at intervals much lower than the designed specification life limits. The goal is to increase intervals towards levels consistent with specification inspection/life limits through engineering evaluation of the engine sample inspected in the LTF program. These inspections are done ahead of the fleet in order to gain confidence that the fleet is safe to continue flying past that interval.

At each inspection interval, an ACI, or analytical condition (or component) inspection, is accomplished on a specified number of engines and components designated to be inspected. Due to operational and logistical constraints,

however, that number is often reduced. The engineers must then make a determination of how many engine component inspections will still be adequate to determine if the rest of the fleet can continue flying.

Problem Statement

A problem exists in the method currently used to determine the number of engine components to be inspected in an ACI program. Currently, that determination is based on past program sample sizes and engineering estimates agreed upon by experienced engineers but not based on any statistical analysis. Because of this, there is no way to measure precisely the value of using one sample size versus another to model the fleet. When logistical and operational problems reduce the number of components that can be inspected, the manager must decide whether to continue flying based on uncertain information or to ground the fleet until the ACIs can be completed.

Research Objectives

The objectives of this research are: (1) to determine what sample size of components is required to have some specific level of confidence that the inspection interval for the fleet can be increased, (i.e., the fleet can continue flying past that initial interval safely); (2) to determine the risk or decrease in confidence that is associated with a less-than-optimum sample size.

Scope

As a result of this study, a valid measurement tool with which to determine the proper sample size for an ACI program will be developed. The model will not attempt to assess the quality of the management decisions needed to input into the model. Those decisions are: (1) the determination of an acceptable number of components that pass inspection before the inspection interval can be extended, and (2) the selection of the confidence level desired in the results. Those decisions are built into the model in various option levels.

Limitations

The major limitation in this study is that the sample of engines and components drawn for the ACI program is not drawn randomly. This is discussed in the 'Sample' section. The major drawback is that the confidence intervals developed for this model will be less precise than those developed had the sampling been done randomly.

Another limitation of this study is that the sample size determination is completely dependent on the two management decisions, (1) the determination of an acceptable number of components that pass inspection before the inspection interval can be extended, and (2) the selection of the confidence level desired in the results. The result of these decisions can significantly change the resulting sample size answer obtained from this model. Therefore, a

manager must set strict criteria from the outset and not change that criteria due to new developments.

Assumptions

Some assumptions basic to an ACI program are as follows:

1. Complete engines and individual engine components are inspected in an ACI program. For the purposes of this study, it can be assumed that whenever an ACI is being discussed, it refers to engines and engine components, even if not stated explicitly.
2. It takes a specified number of acceptable engines/components to pass inspection before the inspection interval can be extended. That specified number is not defined here, but is chosen by management.
3. If that specified number of engines/components pass inspection, the inspection interval is extended with the assumption that the inspected engines/components adequately represent the fleet.

These assumptions underlie the methodology chosen and discussed in detail in the following chapter.

II. Methodology

Overview

This chapter describes the methodology used to accomplish the research objectives previously stated. The options that the manager can choose in an ACI program will be grouped into discrete levels and then a statistical analysis will be used to determine the proper sample sizes for those levels with varying levels of associated confidence. This analysis will then be presented in the form of a simple model to be used as a quick reference by the manager to help make decisions regarding ACI sample sizes. This chapter describes the population for which the model is designed, the assumptions underlying the model, and the statistical tests and computer program used to develop the model.

Population

The population for which this statistical analysis is designed consists of each fleet of new USAF jet engines coming into the inventory which will require a LTF program. Therefore, there is not one specific target population, but a set of populations which will range in size depending on the specific engine program.

Sample

The samples taken from each population will not be random samples. They will be nonprobability, purposive samples. More specifically, they will be judgment samples, handpicked to conform to the criteria of an ACI program. By definition, ACIs are performed on the LTF-designated engines or on non-LTF high-time engines. These engines are purposefully flown under accelerated flying schedules to achieve the goals of the LTF program.

LTF programs will vary in size from engine program to engine program. Each program designates a specified number of the first operational aircraft/engines to be involved in the LTF program. Of this subset, the ACI hardware forms another subset composed of the high-time LTF engines. (Sometimes, components that are not LTF-designated hardware are chosen for ACIs because they have accrued high time.) For example, consider a new engine program with an expected fleet of 500 engines, (500 engines are to be built). Of that fleet, (population), the first 100 engines are designated LTF engines. Of that 100 engines, a sample of 10 will be required for an ACI program.

The manner in which ACI engines and components are chosen is actually based not only on the amount of hours accrued, but on maintenance convenience. If an ACI is underway for certain components nearing the 500 engine operating hours (EOH) mark, a component with 471 EOH being shipped to the depot for other maintenance action could be

designated then as an ACI candidate. This eliminates unnecessary maintenance actions in the field to remove other high time components that are otherwise operating normally. Thus, the sample of engines and components in an ACI program is not drawn randomly. It is drawn mainly based on high time criteria, but partially based on maintenance convenience.

Justification for Assuming a Random Sample

Though the preceding section specifically stated that this research is not based on a random sample, this section will justify why statistical techniques based on the assumption of a random sample, will be used.

First, this is the only possible method of sampling due to the very purpose of the LTF/ACI program. That purpose, again, is to identify failure trends in engines and components before the problems are experienced by the entire fleet. Because these engines are the first out of production and into operation, they can be considered the 'worst case scenario'. They do not have the improvements often developed as experience is gained. The biggest contributor supporting the 'worst case scenario' is that these engines are flown twice the normal number of hours per month as the rest of the fleet in order to gain an inspection lead over the rest of the fleet. Therefore, the sample may not statistically represent the average fleet engine, but if biased, will be biased towards the worst

case. For safety of flight reasons, this bias is acceptable. For logistics planning reasons, this bias may prove to provide more costly estimates. It is assumed for the purpose of this study, however, that safety of flight considerations are more important than logistical considerations, so the bias is appropriate.

Secondly, while these engines should be considered biased towards the worst case, if biased at all, it must be remembered that the LTF engines are maintained by the same standard technical data as the entire engine fleet. No special maintenance is performed. Also, these are production engines that represent the fleet at the time of production.

Lastly, this research is not designed to replace management and determine absolutely the sample sizes required for each LTF/ACI program. It is intended, instead, as a tool to help management make those decisions when faced with conflicting engineering, logistical, and operational inputs. Sample size determinations are currently based on past program sample sizes and engineering estimates agreed upon by experienced engineers but not based on any statistical analysis. This research is intended to provide a measure of the relative confidence a manager can place in assuming that the entire fleet will reflect this sample, or at least be no worse than it.

Data Collection

Due to the nature of this research, there is no actual data to obtain. The data needed to use the finished model will be provided by each manager involved in an ACI program and will be specific to that program.

Definitions

The following definitions will be used in this research:

1. The acceptance number, a = the number of components predefined by management to determine an adequate number of components that pass inspection before the inspection interval can be extended.

2. n = the sample size of engines/components in the ACI program.

3. p = the proportion of 'successes' in the sample size, n ; $p = Y/n$ where Y equals the number of engines that pass the inspection or are a 'success'.

Developing the Model

The actual model will consist of summary graphs showing required sample sizes to ensure varying confidence levels for varying levels of an acceptance number of components that pass inspection and within specified ranges of error. The model will also consist of backup tables showing the data in more detail. In this way, the manager of a dual-engine aircraft with less stringent safety requirements than a single-engine aircraft can define a smaller acceptable

number than does the manager of the single-engine aircraft. He/she would then look up that requirement in the tables and find the sample sizes required for various confidence levels. Those confidence levels reflect the confidence the manager can have that an acceptable number of the remaining fleet will also pass inspection.

In this model, p , the proportion of engines that pass inspection, represents the first management decision, the determination of an acceptable number of components that pass inspection before the inspection interval can be extended. The manager converts that acceptable number to a proportion by dividing by the total number in the sample, n . Then the manager can choose from a range of values for p .

The second management decision, the selection of the confidence level desired in the results, is reflected in the tables by C.L. (confidence level). The manager can choose from confidence levels ranging from 55 to 95%. Realistically, it is assumed that no manager would select 55% confidence, but these values will be given to show comparisons. The actual graphs will reflect the design of Figure 1.

Statistical Analysis

Because humans have serious performance deficiencies as intuitive statisticians, an experienced engineer's judgment as to the sample size required for an ACI program may not be as valid as his/her judgment on other technical

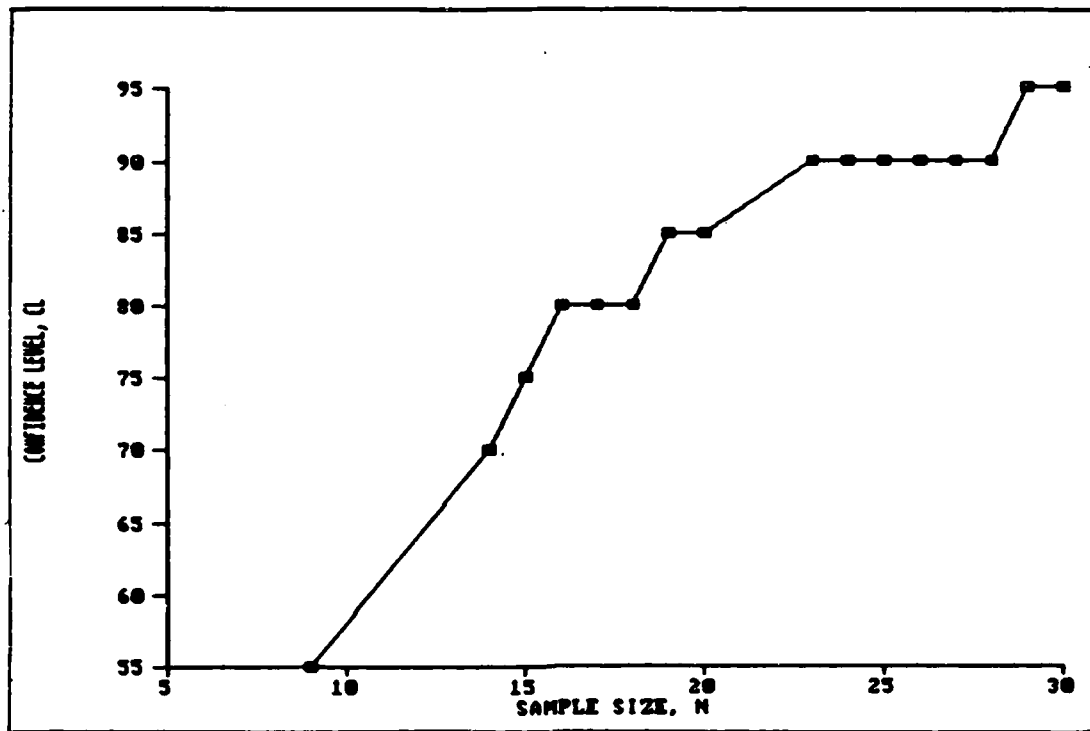


Figure 1. Example Graph

issues (13:284-298). One of the deficiencies identified by research is 'the lack of intuitive understanding of the impact of sample size on sampling variance' (2:248). A study by Tversky and Kahneman 'found that the investigators did not seem to perceive correctly the error and unreliability inherent in small samples. Other studies with students suggest humans do not understand random error effects in small samples' (2:248). The research cited only strengthens the argument that engineering judgment should be supplemented with a statistical tool to measure the value (gains or losses in prediction accuracy for the engine fleet) associated with various sample sizes in an ACI program.

The model used in this study will be based on a binomial probability distribution for small sample sizes. It is binomial because each element can be considered a success or failure; i.e., the component passed or failed inspection. Also, when the sample size is small, the normal approximation does not apply and the exact binomial probabilities are used to calculate confidence intervals.

The assumptions leading to the binomial distribution are:

1. The ACIs consist of n inspections, where n is fixed in advance of the inspections.
2. The inspections are identical, and each inspection can result in one of the same possible outcomes, either passing (success) or failure.
3. The inspections are independent, so that the outcome on any one inspection does not influence the outcome on any other inspection.
4. The probability of success is constant from inspection to inspection.

Computer Program

The binomial probability distribution has been modeled in a computer program written by Dr. Donald Marx at the School of Business, University of Alaska. This program will be used to determine the sample sizes used in the model. The computer program uses the exact binomial probability equations for sample sizes less than 126 and the normal

approximation equations for sample sizes greater than 126. This computer program will be presented in more detail in Chapter IV.

The following chapter will review existing literature on LTF/ACI programs highlighting past LTF/ACI programs and the purpose of these programs.

III. Literature Review

Introduction

In February 1974 the Air Force was directed by the DOD Planning and Programming Guidance Memorandum for FY76-80 to 'implement for all new aircraft entering operating service in FY77 and beyond a reliability-centered maintenance (RCM) strategy' (12:I-9). One of the major features of this RCM strategy is a Lead-The-Force (LTF) program.

Topic Statement

This literature review will examine the concept of the Lead-The-Force/Analytical Condition Inspection program as it relates to the determination of sample sizes for the ACIs.

Justification

One of the major elements of the reliability-centered maintenance program is the analysis of wear rates, failure modes and causes, and their effects on critical engine components (12:V-36). A Lead-The-Force program provides vital information for that analysis. The early identification of failure trends and problem areas is 'useful for workload and logistics planning [establishing inspection and maintenance cycles], improving maintenance procedures, testing the validity of parts' life limits, and identifying components in need of redesign' (12:V-37).

Plan of Development

This review will first describe the objectives and guidelines of an engine LTF/ACI program as presented in Air Force manuals and organization-level briefings and reports. It will then present past and current LTF/ACI programs including problems experienced on those programs.

Analysis of the Literature

For a new weapon system a Lead-The-Force program and its complement, Analytical Condition Inspection (ACI), is a program that subjects the first or selected aircraft and engines out of production to an inspection program that will be used to assess the entire fleet.

Purpose. The major purpose of a LTF/ACI program is to 'identify failure trends and problems in engines and their components before the problems are experienced by the entire fleet' (12:V-36). LTF programs provide early intelligence on engine integrity, reliability, and maintainability and provide engineering and procurement lead times for orderly updating and modification of the engine (5:1).

The objectives that must be met for a LTF program to be successful are:

- to identify potential premature engine component wear rates and failures by early analysis of trends/failure rates and to assist in the definition of corrective action;
- to assess scheduled inspection and maintenance requirements;

- to rapidly advance engine accessory operating hours consistent with the capability of the hardware;

- to identify potential impacts on future spares support;

- to identify hardware life impacts on system support costs (5:2).

It should be noted here that LTF/ACIs only detect chronic wear-out failure modes: the fleet will uncover the statistically remote problems (11:4).

Key Participants. The Aeronautical Systems Division (ASD) at Wright Patterson AFB, OH has the overall responsibility for the Lead-The-Force engine programs. The using commands and operating bases have the responsibilities of operation, maintenance, and data reporting. The engine prime depot assigned to the engine program is responsible to either perform, or assist the contractor in performing, the ACIs. The depot also has repair, support, and reporting responsibilities. The contractor provides engineering support and technical reports (5:5).

Guidelines. Some basic guidelines for a LTF/ACI program are that the selected engines are kept as complete units with minimum parts replacement, maintenance actions are recorded, and the engines are modified in accordance with the latest Time Compliance Technical Orders (TCTOs) and approved Engineering Change Proposals (ECPs) (5:4). Also, the engines are operated under accelerated flying schedules of at least twice the fleet average, and receive priority in

maintenance queues at all levels (12:V-37). By following these guidelines and performing ACIs, the Air Force can determine the validity of parts' life limits and whether component redesign may be necessary (12:V-37).

ACIs. Analytical condition inspections requirements can change from engine program to engine program. Also, different components within the same program can have different ACI requirements. These conditions vary and are predicted primarily by whether a multi-engine or single-engine aircraft is involved. Components that are considered flight or safety critical have stricter requirements than other components. For this study it is not necessary to know the specific ACI requirements for each component. In general, ACI requirements can range from basic recalibration of a component to identify any shifts in its performance since production testing, to a complete teardown of a component to map areas of excessive wear and check seal and bearing conditions. The inspection criteria is defined by the program engineers.

ACIs are performed at different engine operating hour (EOH) intervals for different components. Examples of initial intervals for ACIs are 500, 750, and 1000 EOH. Again, the program engineers determine the initial intervals and the subsequent inspection intervals.

The data obtained from LTF/ACI programs is primarily used to base engineering and management decisions to extend

the inspection intervals for the fleet. The data is also used to identify problems with current maintenance practices, limits, and overhaul intervals (12:V-38).

The concept behind the LTF/ACI program is that a sample of engines with accelerated operating hours can represent the future status of the entire fleet. This is not to say that no other information or experience is used to make decisions concerning the fleet. There is a wide range of other information available to the manager in the form of development test data, flight test data, and other engine program experience. However, the LTF/ACI program provides the first information on actual operational experience for that specific new engine. It is, therefore, a heavily weighted source of information, and the methods used to apply that information are equally important. This is the reason that sample size determination for the ACIs should be based on a statistical analysis. Then if a small sample size is chosen due to logistical or operational support problems, the manager can determine the level of confidence he/she can apply to the data from the ACI program. The manager may find that it is necessary to obtain more substantial data from other sources to justify certain decisions. On the other hand, the manager may find that the number of inspections can be reduced with little impact on the level of confidence, saving cost and time.

Past and Current LTF/ACI Programs. As stated in the introduction, in 1974 the Air Force was directed by the DOD Planning and Programming Guidance Memorandum for FY76-80 to "implement for all new aircraft entering operating service in FY77 and beyond a reliability-centered maintenance (RCM) strategy" (12:I-9). One of the major features of this RCM strategy is a Lead-the-Force program. Lead-the-Force programs are outlined in AFR 66-28, "Lead-The-Force Programs". Since 1977, the following programs have implemented a LTF/ACI program: the F100-PW-100 and F100-PW-200 engine programs for the original F15s and F16s, respectively, the F110-GE-100 and F100-PW-220 engine programs that will update the F15s and F16s, the F110-GE-129 and F100-PW-229 engines, improved versions of the F110-GE-100 and F100-PW-220 still in the development phase, the F101-GE-102 engine in the B-1B, and the ATF program which will be developing a LTF/ACI program as it advances. From this list it is clear to see that only two contractors to date have experience with a LTF/ACI program, those being Pratt and Whitney Aircraft Engine Company and General Electric Company, Aircraft Engine Business Group. Of those engines listed, only the F100-PW-100s and -200s have actually completed their LTF/ACI programs. The F100-GE-100, F100-PW-220, and F101-GE-102 LTF/ACI programs are currently underway.

According to Henry Ibarra, author of the original ACI plan and the majority of follow-on documentation, the

limited amount of experience with these LTF/ACI programs has been beneficial (4). The initial ACI inspection done at 250 hours on the F100-PW-100 program found several problems that were to become significant later. They found exceptional wear on the #4 bearing knife edge seals, distressed (burnt) augmentor liners ("screech liners") and distress of the nozzle convergent and divergent seals and flaps (4). The discovery of these conditions early-on allowed corrective action to be taken for the entire fleet, thus preventing any possible premature engine failures due to these defects. It should be stressed here that these conditions were found once the system went operational; development tests and accelerated engine testing were not enough to make the problem apparent.

Presented as an example, Table I shows the actual F100-PW-100 experience on several components in its ACI program (1:2).

Table I. F100-PW-100 Experience on Several ACI Components

<u>COMPONENT</u>	<u>INITIAL MOH</u>	<u>CURRENT MOH</u>	<u>MATURE MOH</u>
Main Fuel Pump	300	1000	800
Hydraulic Pump	300	900	2000
Unified Fuel Ctl	300	1500	4000
Tt2.5 Sensor	300	3000	4000

-MOH Maximum Operating Hours (1:2)

This table shows how the ACI program enabled the replacement schedule in the aircraft technical order to be grown ahead of the fleet. When a replacement schedule is

'grown' ahead of the fleet, replacement dates are pushed further away from original dates, delaying the eventual replacement of components. The replacement schedule initially designated these components to be replaced every 300 engine operating hours. The purpose of the ACI program is to inspect the LTF/ACI hardware (which have twice as many engine operating hours as the rest of the fleet) and increase the replacement schedules of that hardware which has passed the inspection. The T.O. is then updated to reflect the new schedules; this allows the rest of the fleet to continue uninterrupted flying past that old inspection interval. Concurrently, action is taken to alert the prime Air Logistics Center (ALC) inventory manager to adjust replacement factors of spare parts. Table I shows the current F100 replacement schedule and the mature replacement schedule the program hopes to reach. The mature schedule is based on the engine specifications (5:4). In general, the specification calls for 2000 engine operating hours if the component is a 'hot' part meaning hot fluids or gases pass through or around it, and 4000 engine operating hours if the component is a 'cold' part.

As Table I shows, not all components grow at the same rate. The more critical the component, the slower the growth generally. Also, each engine program manager designs tailored ACI schedules. For example, the initial ACI schedule for the F110 engine was more conservative (had shorter inspection intervals) for some components compared

to the F100 due to the fact that the F110 has a single-engine (F16) application, whereas the F100 has a dual-engine (F15) application (1:5).

Problems Faced in an ACI Program. There are several problems faced in an ACI Program. One problem is that engine controls and accessories cannot be kept with any one specific engine. The engine ACIs become a complex issue because the controls and accessories (C&A) on the engines are changed out so frequently. Previously, it was stated that a basic guideline is to keep the engine as a complete unit. Unfortunately, the maintenance crews must also keep the aircraft flying twice the normal number of hours for the fleet. To do that, maintenance crews must sometimes remove two or three controls and/or accessories at one time to ensure solving an immediate problem and send the aircraft out in time for its next mission. C&A can spend months in the repair cycle since they must be shipped back to the vendors and, there, compete for test benches with needed production units. Because the engine controls and accessories do not usually stay with their original engine they are treated separately in ACI programs.

The general plan is to use the C&A on the LTF-designated engines; however, it should be recognized that since in the early stages of field introduction, the designated LTF engines/components will not be able to accrue sufficient exposure to place them significantly ahead of the fleet,

high time, non-LTF engines/components should be selected for ACIs' (8:5). (Controls and accessories are tracked individually by serial number under CEMS (Combined Engine Maintenance System), thus the operating times for each component are available.)

The fact that the controls and accessories do not remain with any one engine is only one problem. The major problems experienced on ACI programs have been the availability of replacement components (spare parts) as the inspection intervals are encountered and also the component vendors' capabilities to support the effort. The issue of spare parts is one that can be avoided if parts support for the ACI program is integrated into the production plan from the beginning. If a program reaches the first inspection intervals and spare parts are not available, there is a problem. If the depot cannot provide parts support, parts are borrowed from flight test spare parts, the CIP program, or the engine production line; however, the original ACI plan is usually altered to reflect the limited resources.

The same result occurs when the component vendors have limited capabilities to support the ACI program. The problem is that the vendors must continue producing components to keep up with the production schedule, yet the initial inspection interval has been reached so components are being shipped to the vendors for inspection at the same time. Testing equipment and personnel that are assigned to

production hardware must now be used for ACI inspections. This is a problem that can also be avoided if the ACI program is planned out early in the development program. However, due to the limited experience with these programs, the AF and the contractors are still in the learning stages.

Currently, the F110-GE-100 engine program at ASD is experiencing both a shortage of spare parts and concerns about vendors' capabilities to support the ACI effort (10:4). Because of these concerns, negotiations are being made over the numbers of each component that can be inspected and at what intervals those inspections can be supported. This study was prompted by the problems experienced on this program.

Components Inspected in an ACI Program. Each engine program manager must tailor the ACI program to meet the program's needs. There are, however, many similarities between the ACI programs to date. This is due to the fact that only two contractors have taken part in the ACI programs and because for each contractor, the engines involved so far have been derivative engines built upon a basic engine but with improved capabilities in each new generation.

As a consequence of this, the components to be inspected in the ACI programs remain similar in number and type from program to program. For instance, very similar lists of components would be found in the F100-PW-100 and -200

programs, as well as in the F110-GE-100 and -129 programs. Table II will give the reader a basic feel for the number and types of components involved in ACI programs currently underway.

Table II. F110-GE-100 Controls and Accessories
Addressed in ACI Program

Main Fuel Pump
Main Engine Control
Augmentor Fuel Pump
Lube and Scavenge Pump
A8 Hydraulic Pump
Fuel Boost Pump
Augmentor Fuel Control
Engine Monitoring System Control
Fan Speed Sensor
Generator, Rotor/Stator
Lube Temperature Sensor
Oil Pressure Transmitter
Fuel/Oil Cooler
Hydraulic Heat Exchanger
T2 Sensor
Lube Tank
Augmentor Fuel Temperature Control
Engine Monitoring Systems Processor
Main Ignitors
Augmentor Ignitor
IGV Actuator
VSV Actuator
A8 Actuators
Anti-Ice Valve
T25 Sensor
Ignition Exciter
T4B Pyrometer

(1:6)

Summary

This literature review examined the concept of the Lead-The-Force/Analytical Condition Inspection program as it relates to the determination of sample sizes for ACIs. The review identified the purpose for a LTF/ACI program, who the key participants are, and some guidelines to be followed when implementing LTF/ACI programs. It also presented a history of the past and current LTF/ACI programs and looked at the most common problems encountered in these programs. Lastly, the literature review presents as an example, a listing of components actually inspected in one ACI program to give the reader a basic understanding of what components are involved.

Several main points stand out in this review. First, the major purpose of a LTF/ACI program is to identify problems in new engines and components before the fleet experiences them. The information provided in a LTF/ACI program is used to increase flight safety and provide lead times for engineering changes and spare parts procurement.

Second, because it is difficult to determine parts conditions and which parts will require replacement before the ACI begins, acquisition of replacement parts for the initial ACIs is sometimes difficult. In some instances parts have been borrowed from the engine production line, flight test spare parts, and the CIP program in order to expedite return of LTF engines back to the field. Other

times, the actual number of ACI inspections has been reduced.

Third, the concept behind the LTF/ACI program is that a sample of engines can be used to represent the entire fleet. Due to the logistical planning factors and flight safety decisions that are based on the ACI results, poor up-front sample size determination or poor ACI sample sizes resulting from logistical problems encountered during the program can lead to greater costs and logistical problems in the long run.

IV. Findings and Analysis

Statistics

Binomial Probability Distribution. During an ACI program, engines and/or components are inspected by a team of engineers and determined to pass or fail the inspection. Program management presets a required acceptance level for the proportion of engines that must pass inspection before the inspection interval can be extended for the rest of the fleet. The inspection process, therefore, meets the requirements for a binomial experiment. The requirements for a binomial experiment are the following:

1. the experiment consists of n trials (inspections), where n is preset by program management;
2. the trials (inspections) are identical and each trial (inspection) can result in one of the same two possible outcomes, either success (passing inspection) or failure;
3. the trials (inspections) are independent so that the outcome on any particular trial (inspection) does not influence the outcome on any other trial (inspection);
4. the probability of success (passing) is constant from trial to trial (or inspection to inspection) (3:98).

Given a binomial experiment consisting of n trials, there is a binomial random variable, Y , defined as the number of successes among the n trials (3:98). Texts use

the notation $Y \sim \text{Bin}(n, p)$ to indicate that the binomial random variable depends on two parameters, the n trials with probability p (3:100). The binomial probability distribution is denoted by

$$b(y:n, p) = \begin{array}{ll} \text{number of ways of} & \text{probability of} \\ \text{choosing } y \text{ of the } n & \text{any such} \\ \text{trials to be successes} & \text{outcome} \end{array} \quad (1)$$

or,

$$b(y:n, p) = \begin{cases} \binom{n}{y} p^y (1-p)^{n-y} & y = 0, 1, 2, \dots, n \\ 0 & \text{otherwise (3:102)} \end{cases} \quad (2)$$

(Note: Most texts use the variable 'x' instead of 'y'. The variable, 'Y', is used here, however, to remain consistent with notation in the computer program used in this study to generate exact binomial probabilities and the associated confidence intervals.)

'Even for a relatively small value of n , the computation of binomial probabilities can be tedious' (3:102). This is due partly to the combination, $\binom{n}{y}$, in the computation of binomial probabilities. A combination is defined as follows:

$$\binom{n}{y} = \frac{n!}{y!(n-y)!} \quad (3:50) \quad (3)$$

Another factor adding to the tediousness of computing binomial probabilities is the fact that the next two factors in the formula are raised to powers, $p^y (1-p)^{n-y}$.

If n is sufficiently large, the Central Limit Theorem can be used to approximate the binomial distribution and relieve the difficulty found in the binomial distribution

computations. It is not necessary to review the Central Limit Theorem in this study, except to say that for large sample sizes the calculations for approximating the binomial probabilities become significantly easier. Those approximations can be used if both $np \geq 5$ and $n(1-p) \geq 5$ to ensure that n is large enough for the Central Limit Theorem to be accurate.

The problem faced in an ACI program is that the sample sizes considered are too small to apply the Central Limit Theorem. After extensive research to find information on small sample binomial statistics for this study, only one source was found that provided exact confidence bounds calculations for sample sizes from 1 to 30. Dr. Donald Marx, Associate Professor of Quantitative Methods at the School of Business and Public Affairs at the University of Alaska has done much research in this area and published a paper that appeared in Computer Science and Statistics: Proceedings of the 18th Symposium on the Interface. His paper, titled 'Exact Confidence Bounds for Proportions' discusses past research done for proportions (number of successes in n trials) using the binomial distribution. Also presented in his paper is a BASIC computer program for constructing exact confidence bounds; his program was used extensively in this study and will be discussed more thoroughly later. The following comments come from Dr. Marx's research. In the past, charts and tables have been available for constructing confidence interval estimates for

binomial distributions. Typical charts, like those available in Pearson and Hartley (1976) (see Appendix A), present two confidence levels (95% and 99%) and sample sizes from 8 to 1000. 'Confidence bounds were constructed by calculating sufficient points using the cumulative binomial distribution function, $F(y;n,p) = \text{constant}$, to draw smooth curves for the upper (UB) and lower (LB) bounds when y 'successes' are observed in a sample of size n' (7:386). The authors state, 'The charts cannot and are not intended to provide very precise readings. Although graphical interpolation can be used to approximate bounds for sample sizes greater than eight that are not explicitly included in the charts, there is no way to use the charts for sample sizes less than eight' (7:386). Dr. Marx's program uses the exact binomial distribution and is valid for as small of a sample size as one.

Statistics Definitions. It is important to define several statistical terms here and explain them in the context of an ACI program. As previously noted, the sample size, n, (also denoted in this study as N% for BASIC programming reasons), is equivalent to the number of engine/component inspections predetermined by program management and engineering to be completed in the ACI program.

Y, (also denoted later in this study as Y% for BASIC programming reasons), is the number of 'successes' or engines/components passing inspection in the ACI sample.

A point estimate for a proportion, p , is a single value based on a sample of observations which we feel is the best possible approximation of the true value of the population proportion (6:134). The point estimate of a proportion, also called the sample proportion, is the number of successes over the sample size, $p = Y/n$. In terms of an ACI, the population proportion is that proportion of engines in the entire fleet which would actually pass inspection. This is the value that the manager does not know; by inspecting a sample of engines the manager seeks to determine an estimate of that population proportion in order to justify making the decision to extend, or not extend, the inspection interval. The point estimate is the estimate on which the manager will base his/her decision. This estimate must therefore be made with minimum error and an adequate level of confidence. In other words, we would like to know how close the estimate is to the true population proportion.

Making the estimate with minimum error and an adequate level of confidence implies that we would like to 'state with a certain 'probability' that it is 'within a particular distance' of the parameter [proportion]. Such an estimate is referred to as an 'interval estimate', an interval of values within which we can state with a certain degree of confidence (i.e. probability) that the parameter falls' (6:136). This interval estimate is called the confidence interval and the endpoints of the interval are called the confidence bounds, or lower (LB) and upper (UB) bound. The

confidence level is the degree of confidence or probability that the true population proportion falls within the confidence interval. For example, suppose a confidence interval for the proportion of engines that pass inspection extends from .85 to .95 and the associated confidence level is 95%. Then we are 95% confident that the proportion of engines that pass inspection in the entire fleet is between .85 and .95. Another way to look at it is that we are almost positive (95% confident) that between 85 and 95 engines will pass inspection in a fleet of 100. This information will be extremely valuable in logistics planning and safety of flight considerations.

Closely related to the concept of the confidence interval is the concept of error, E . Error, as defined for this study, is the amount added to and subtracted from the estimated proportion. For example, a sample size of 10 with a proportion of .8 and an associated error of $E = \pm .1$ would cover the interval from .7 to .9. Think of the magnitude of E as specifying the precision or accuracy associated with the point estimate of the proportion and the given sample size. The smaller the interval, the more precise the estimate of the proportion is; therefore, the error, or precision, is inversely related to the confidence level or reliability of the interval (3:256). We have more confidence in an interval that is long and less confidence in an interval that is very short or precise. If the manager presets the maximum allowable error desired and the

confidence level he/she wants to attain, then the sample size, n , necessary to ensure an interval of length E and confidence level, C.L., can be computed.

Assumptions

As stated already, the manager should preset the proportion of engines that is required to pass inspection before the inspection interval can be extended. Due to the nature of ACIs, typical proportions that managers will preset range from .8 to 1.00. In other words, some managers will determine that at least 80% of the engines must pass inspection before the inspection interval can be extended. For comparison purposes, this study will look at proportions ranging from .7 to 1.00. More emphasis, however, will be placed on the upper end of the range enabling managers to set the highest standards they feel are realistic and supportable.

While not an assumption, another point to be recognized is the discreteness associated with proportions. Because proportions are defined as the number of successes, Y , per sample size, n , the range of possible proportions is not continuous. This is especially important for small sample sizes where the number of proportions is limited. For example, a sample size of 3 can have 1, 2, or 3 successes or proportions of .33, .667, or 1.00. A sample size of 4 can only have 1 - 4 successes, or proportions of .25, .50, .75, and 1.00. This discreteness effect makes comparisons of

equal proportions for varying sample sizes impossible in many cases. This will be discussed further in the section 'Implications as a Management Tool'.

The next assumption made for this study is that managers would like to minimize error and maximize confidence levels. If the confidence level is high and the error is small, the manager has reasonably precise knowledge of the parameter's value (3:250). Since the two concepts are inversely related, a tradeoff must be made. For the purposes of this study, errors no greater than $\pm .175$ are presented; though errors of $\pm .175$ are not expected to be used as an actual standard set by managers, they are presented for comparison purposes. For the same comparison purposes, confidence levels as low as 55% are presented; again, managers are not expected to choose this low level of confidence.

The last assumption made is that the lower confidence bound is more critical for this study than the upper confidence bound. While both bounds are used throughout the calculations, only the lower bounds are used to graph comparisons between sample sizes and confidence limits for varying levels of error. The reason this study concentrates more on the lower bound is that the lower bound represents the minimum that the manager can expect the proportion of the entire fleet of engines that pass inspection to be. For planning purposes, the minimum number of engines that will pass inspection is more critical than the maximum number of

engines that will pass inspection. However, it should be remembered that both the upper and lower bounds are used throughout the study except for the graphs.

Exact Confidence Bounds for Proportions Program

As stated already, this program was written by Dr. Donald Marx from the School of Business and Public Affairs at the University of Alaska. The program was presented in the paper, 'Exact Confidence Bounds for Proportions,' which appeared in Computer Science and Statistics: Proceedings of the 18th Symposium on the Interface in March 1986. The program asks the user to input sample size, $N\%$, the number of successes, $Y\%$, the desired confidence level, C.L., and whether the user wants a symmetric confidence interval or a one-sided interval. Then the program computes and displays the point estimate of the population proportion, the standard error of the estimate, and the exact lower and/or upper bounds. As also stated in the 'Statistics' section, the program is based on the exact binomial distribution, not an approximation method. The formulation involves Taylor Series expansions, factorials, and iterative formulas which necessitated the computer algorithm for implementing the exact procedure (7:386). Marx's program computes the confidence bounds within .00001 accuracy for specified confidence levels from 51% to 99.99% and samples of up to 126 (7:387). Larger sample sizes can be input into the

program but the accuracy cannot be guaranteed; the normal approximation is the bound on the accuracy (7:387).

Program Modification

Dr. Marx's program had to be tailored to fit this study. First of all, while it directly computes exact confidence bounds, it only does so for one set of conditions (sample size, number of successes, and desired confidence level) at a time. This research looks at sample sizes from 1 to 30 by one, 30 to 50 by 5, 50 to 100 by 10, and 100 to 400 by 100 with the corresponding number of successes and confidence levels from 55 to 95% by 10. To process all these points, loops were added to Dr. Marx's program for N%, the sample size, Y%, the number of successes, and C.L., the confidence level. Also, to record the confidence bounds for each condition, statements were added to write the bounds and the associated conditions to an output file that could be input into a spreadsheet.

Once the program was modified, it was verified to still be accurate. Over two hundred data points were cross-referenced to ensure that modifying the program did not change any logic within the program. Both programs, the original and the modified, are included in Appendix D.

Once the data was computed using Dr. Marx's program, a spreadsheet program (VP Planner) was used to find which conditions (sample sizes, number of successes, and confidence levels) produced bounds within specified error

ranges. Using data query commands, those conditions whose upper and lower confidence bounds fell within an error range of $\pm .1$, $\pm .15$, and $\pm .175$ were found. These ranges are used to compare the confidence levels that can be attained for different sample sizes. The purpose is to show the gains (or losses) associated with inspecting X more (or less) engines in an ACI program by showing how much confidence can be gained (or lost) with that increase or decrease in inspection. Doing this will provide the manager with a measurement tool against which to measure logistical, engineering, and cost conflicts in choosing the proper number of engines to inspect. .

Once the data was tabulated, graphs were developed to show at a glance the gains available with each additional engine inspection. Consider for example a manager who originally determines that 100% of the ACI engines must pass inspection with a maximum allowable error of $\pm 10\%$ before the inspection interval can be extended. That manager can use the graphs to determine an appropriate sample size. From the graphs, the highest possible confidence level attained for a sample size of 10 is 65%. Now the manager is faced with a decision to reduce that sample size to 8 or cause major logistical problems. By using the graphs the manager can see that a 10% loss in confidence results from reducing the sample size. The manager has only 55% confidence now that the rest of the fleet will reflect the ACI sample.

Modified Program Limitations

Because the program was specifically tailored for this study, the modified program has certain limitations that should be known by anyone attempting to use it for another purpose. First of all, because loops define the values for sample size, $N\%$, the number of successes, $Y\%$, and the confidence level, C.L., the module for $Y\% = 0$ is never invoked and was ignored in the modification. It is unknown if inputting $Y\% = 0$ in the program would cause any problems in that module. Also, the model no longer tells the user when the sample size is too large or the sample proportion is too near $1/2$ to compute the exact binomial distribution. This was a possibility in the original problem when the sample size was greater than 126. For this study, it is not necessary to know this information since the cost of sampling 126 engines/components is far too prohibitive to consider doing. Normal approximations that may be invoked past $n = 126$ are accurate to two decimal places which is accurate enough for this study. The emphasis in this study is placed on accuracy for small sample sizes. Only readers planning to use this modified version need to be concerned with these limitations; the limitations have no consequences in this study.

Data Analysis

As stated previously, the data created with Dr. Marx's program was input into a spreadsheet program (VP Planner).

Using the spreadsheet program, the data was put into tables of six columns: sample size, $N\%$, number of successes, $Y\%$, confidence level, C.L., proportion, p , upper bound, and lower bound. The first three columns reflect the loop logic in the modified program. For example, while $N\%$ stays equal to 4, $Y\%$ varies from 1 to 4 and C.L. varies from 55 to 95% for each different value of $Y\%$. So for $N\%$ equal to 4, there are 36 different cases for which the upper and lower bounds must be computed. For this study a total of 4545 cases were computed.

Once the raw data was tabulated, data query commands were used to identify those cases which met certain criteria. The criteria which was used determined three error ranges, $E=+/- .1$, $E=+/- .15$, and $E=+/- .175$. To do this, the raw data was 'asked' or 'queried' to find those cases which met each criteria. For example, the first criteria asked, 'Is the upper bound less than or equal to the proportion plus .1 and the lower bound is greater than or equal to the proportion minus .1?' In other words, do the bounds fall within a range of $+/- .1$ from the proportion? If so, that case meets the criteria for $E=+/- .1$ and will be 'pulled over' (copied) to another table which identifies only those cases falling within $+/- .1$ distance of the proportion. Appendix B contains the data tables created for $E=+/- .1$, $E=+/- .15$, and $E=+/- .175$. As expected, as the error goes up, the number of cases that meet that error criteria increases. For example, for $E=+/- .15$, all the cases that

met $E = \pm .1$ will be repeated in addition to the new cases which now meet the condition. Below is an excerpt from the $E = \pm .1$ data table to illustrate the format.

Table III. Data Table Excerpt

$E = \pm .1$					
$.95 \leq P < 1.00$	RANGE				
N	Y	CL	PROP	UPPER	LOWER
20	19	55	.95	.9873364	.8645598
20	19	60	.95	.9889049	.8575677
21	20	55	.952381	.9879358	.8707267
21	20	60	.952381	.9894304	.8640275
21	20	65	.952381	.9908812	.8566017
22	21	55	.9545455	.988481	.8763571
22	21	60	.9545455	.9899084	.8699274

The three tables in Appendix B represent all the cases considered for further analysis from this point on in this study. Any case not found in one of these tables has more than .175 error associated with it and, as such, will not provide useful information to a manager. The complete data set generated is presented in Appendix B as reference material only.

Trends

Certain statistical trends should be kept in mind when reviewing the tables in Appendix B and the following graphs. First, for a given error range, the higher the proportion of successes, the smaller the sample size needs to be to attain a specified confidence level. This is why the majority of cases that meet the criteria for a given error range have a proportion of one. For example, at $E = \pm .1$, a sample size

of 10 meets the $\pm .1$ criteria in the case where 10 has the highest proportion of successes possible, 1.00. Note that it is not until the error range is increased to $\pm .175$ that a sample size of 10 meets the criteria with a proportion less than 1.00.

The next statistical fact we should notice is that for a given error range and proportion, the smaller the confidence level, the smaller the sample size needed to meet the criteria. This is why the majority of cases in the $E = \pm .1$ data table have only attained 55 to 65% confidence, and as the error range increases in the following tables, the maximum confidence levels attained also increase. For example, a sample size of 10 in the $E = \pm .1$ range can at most attain a confidence level of 65% even with the proportion of successes equal to 1.00. However, as the error range increases to $\pm .15$, a sample size of 10 can attain 80% confidence; at $E = \pm .175$, it can attain 85% confidence. Note here that a sample size of 10 can never attain more than 85% confidence and remain within $\pm .175$ error even if 100% of the sampled engines pass inspection. This analysis is key to the overall conclusions made in Chapter V. One could use the data tables to determine the maximum confidence levels attainable for varying sample sizes at given maximum allowable errors. It is easier, however, to use the graphs that follow.

Another important trend to notice is that for different confidence levels and constant proportions, the curves

depicting sample size versus the lower bounds are quite similar in shape. The major difference is that the lower the confidence level, the closer the lower bound approaches the proportion; the higher the confidence level, the farther the lower bound is from the proportion (or, the more error is introduced). Also seen in Figure 2 following, as N increases, the lower bound approaches the proportion.

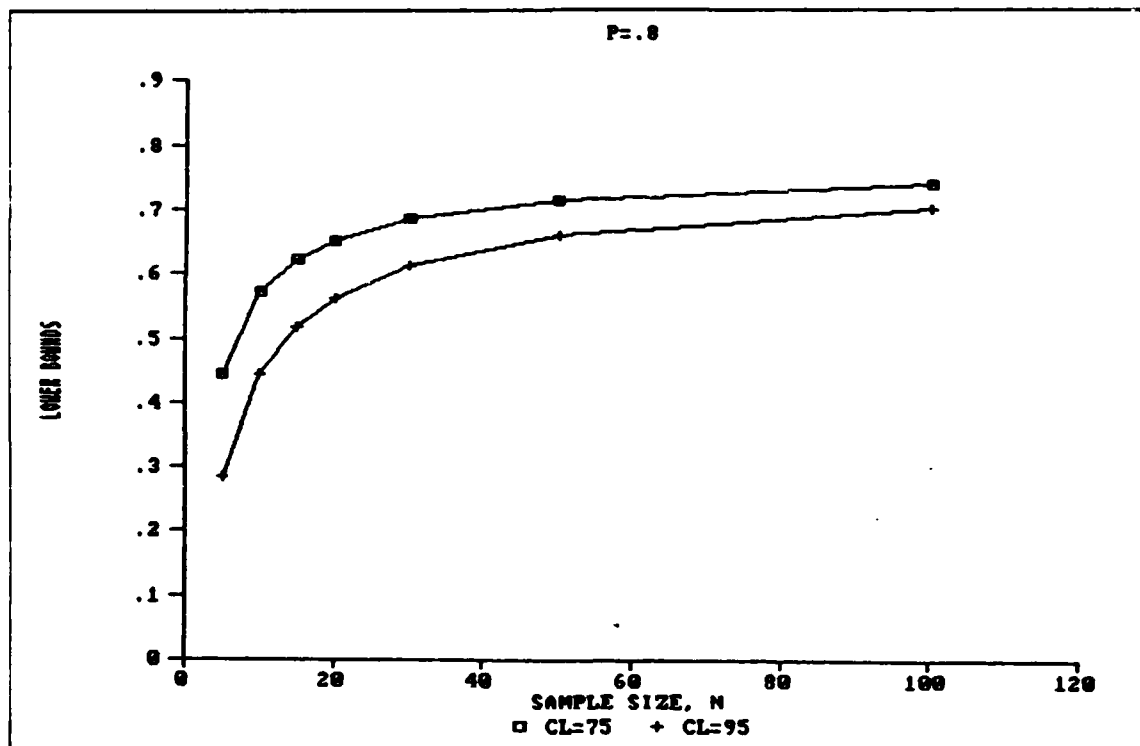


Figure 2. $P=.8$

More importantly, a review of several of these type graphs (p = constant shown over a large sample size range) shows that there is a major change in the slope at a sample size of $N = 20$ no matter what proportion is chosen. There is also a significant change in slope from $N = 1$ to 10 to $N = 10$ to 20. Following are Figures 3 through 8 showing this

phenomenon. The importance of this is that from $N = 1$ to 20, the value of each additional engine inspection significantly outweighs the value of one additional inspection past $N = 20$. While managers may find 20 engine inspections non-supportable due to prohibitive costs and logistical reasons, this analysis shows there is significant increasing value in each additional engine inspection done in the small sample size range of $N = 1$ to 20 and especially in the range $N = 1$ to 10.

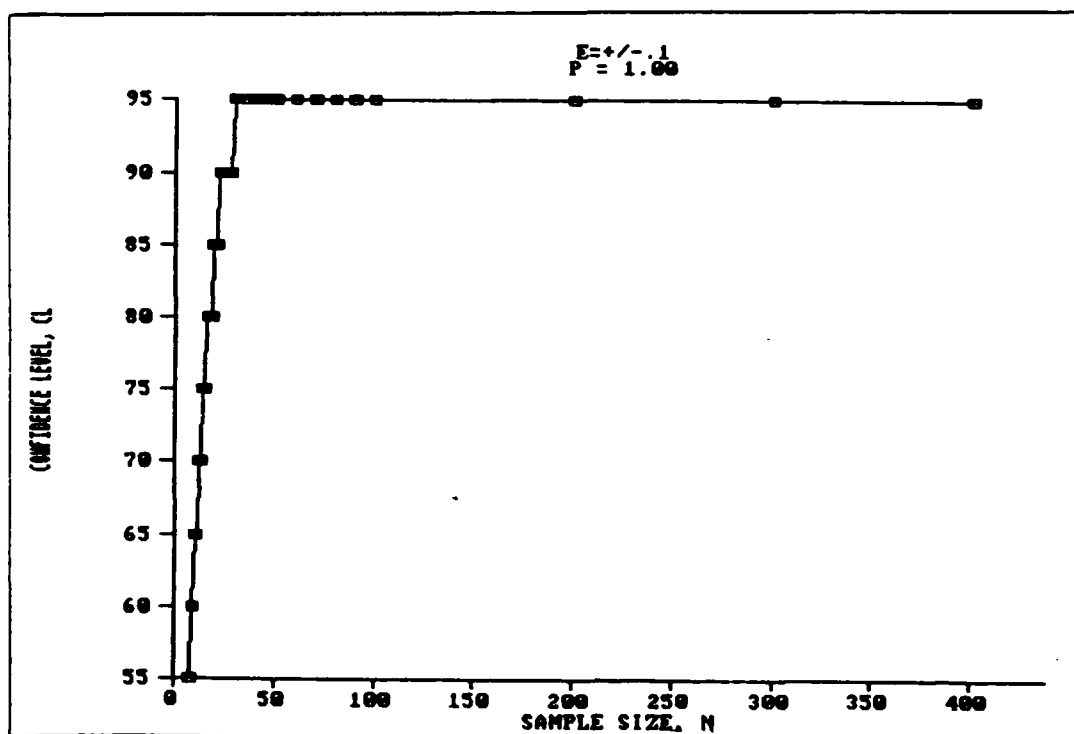


Figure 3. $E = \pm 0.1$ $P = 1.00$ $N = 400$

This is more clearly shown in the following expanded graphs for $P = 1.00$, Figures 9, 10, and 11, showing for each error range the linearity of sample size versus confidence level from $N = 1$ to 10 and the step-function effect from

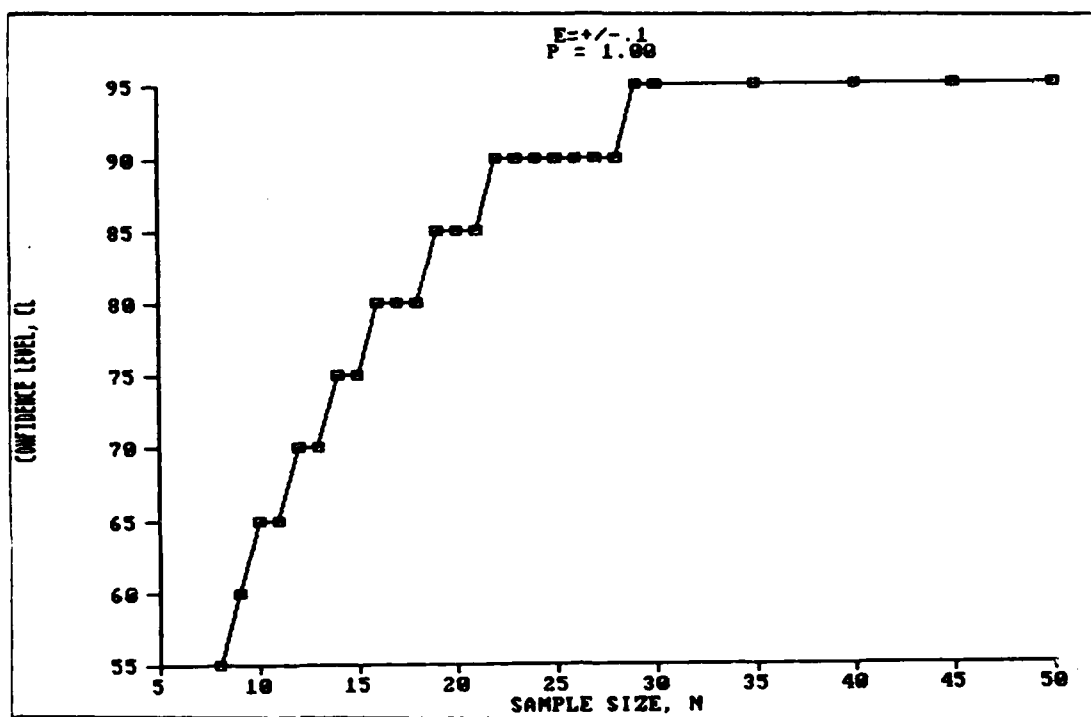


Figure 4. E=+/-0.1 P=1.00 N=50

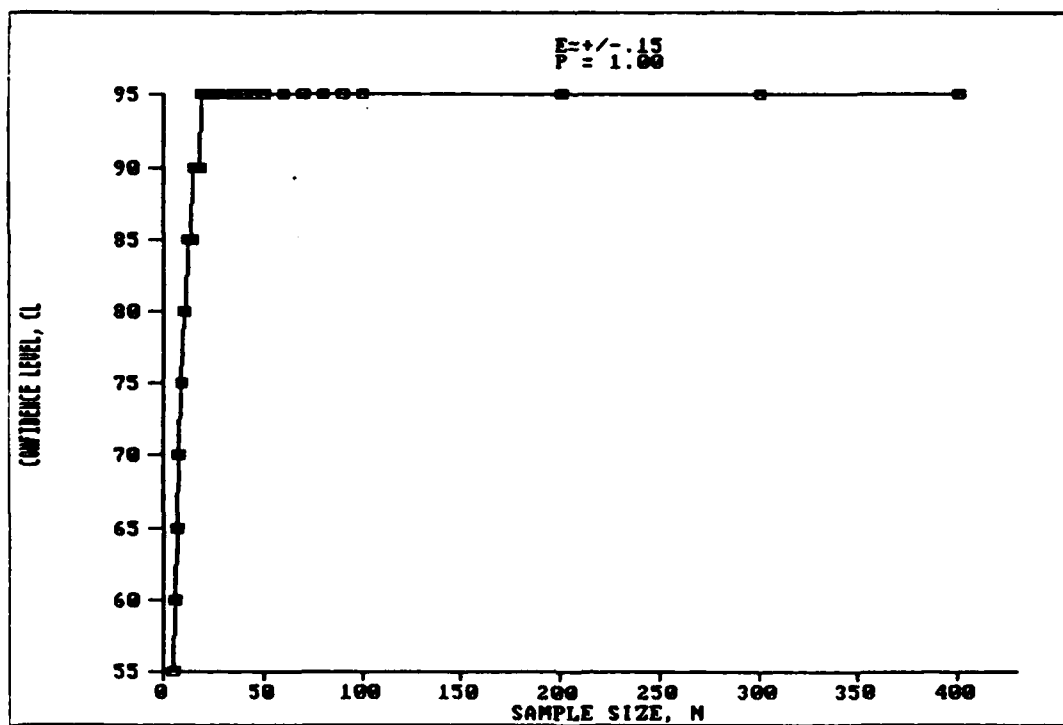


Figure 5. E=+/-0.15 P=1.00 N=400

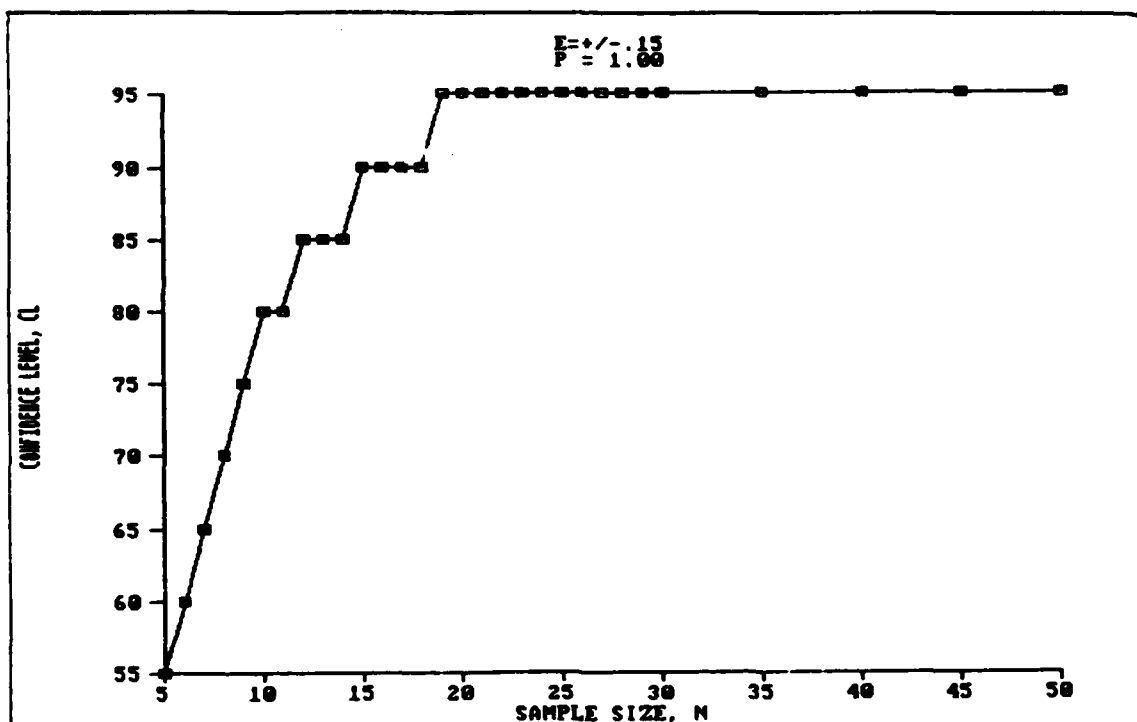


Figure 6. $E = \pm 0.15$ $P = 1.00$ $N = 50$

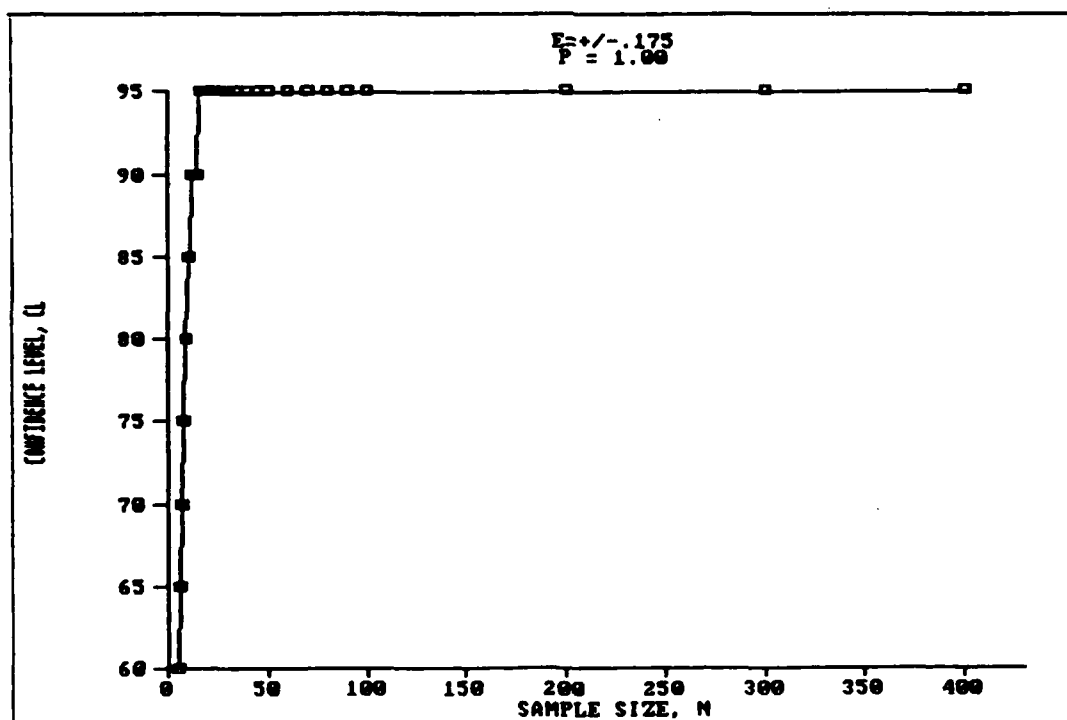


Figure 7. $E = \pm 0.175$ $P = 1.00$ $N = 400$

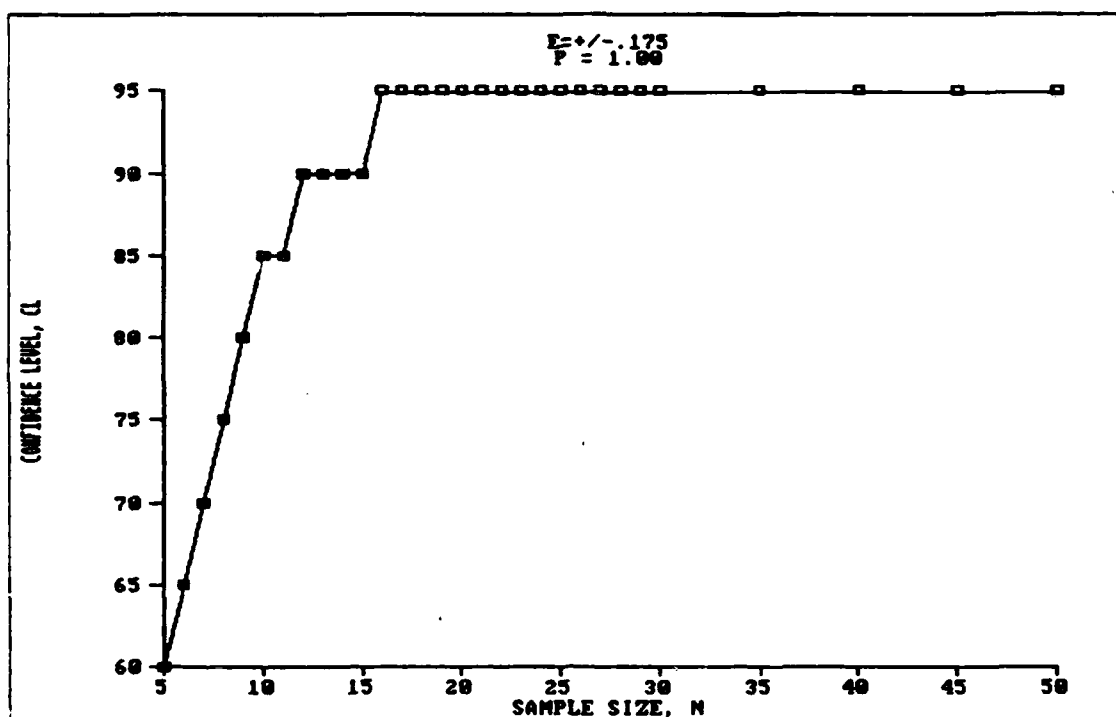


Figure 8. $E = \pm 0.175$ $P = 1.00$ $N = 50$

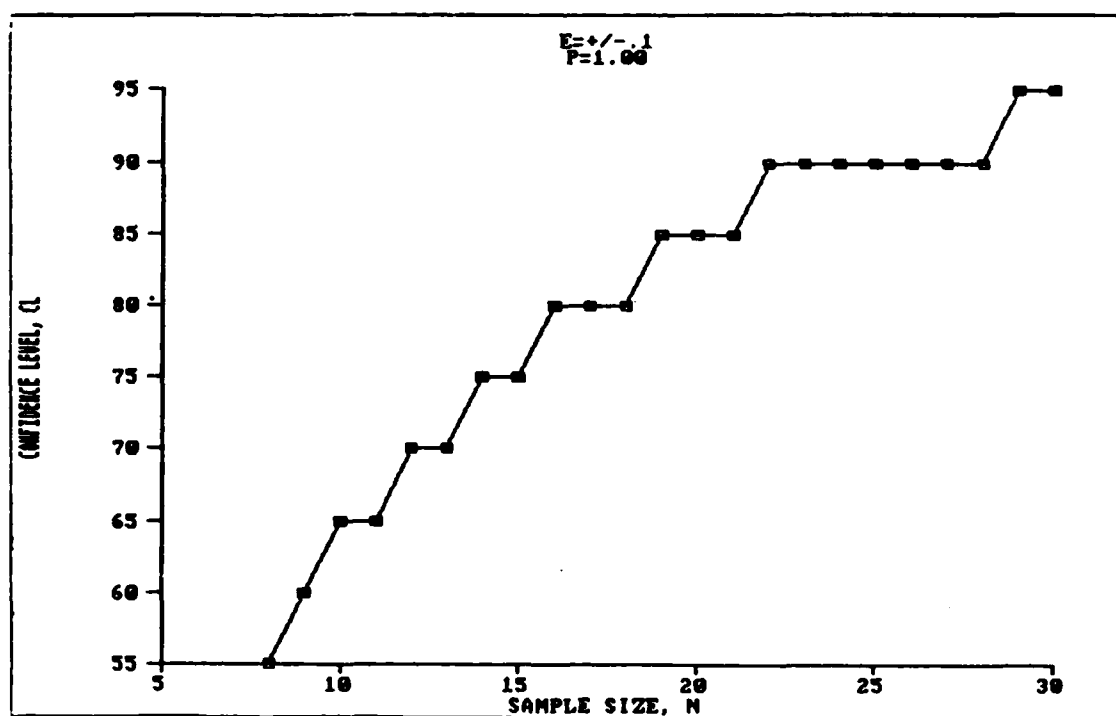


Figure 9. $E = \pm 0.1$ $P = 1.00$ $N = 30$

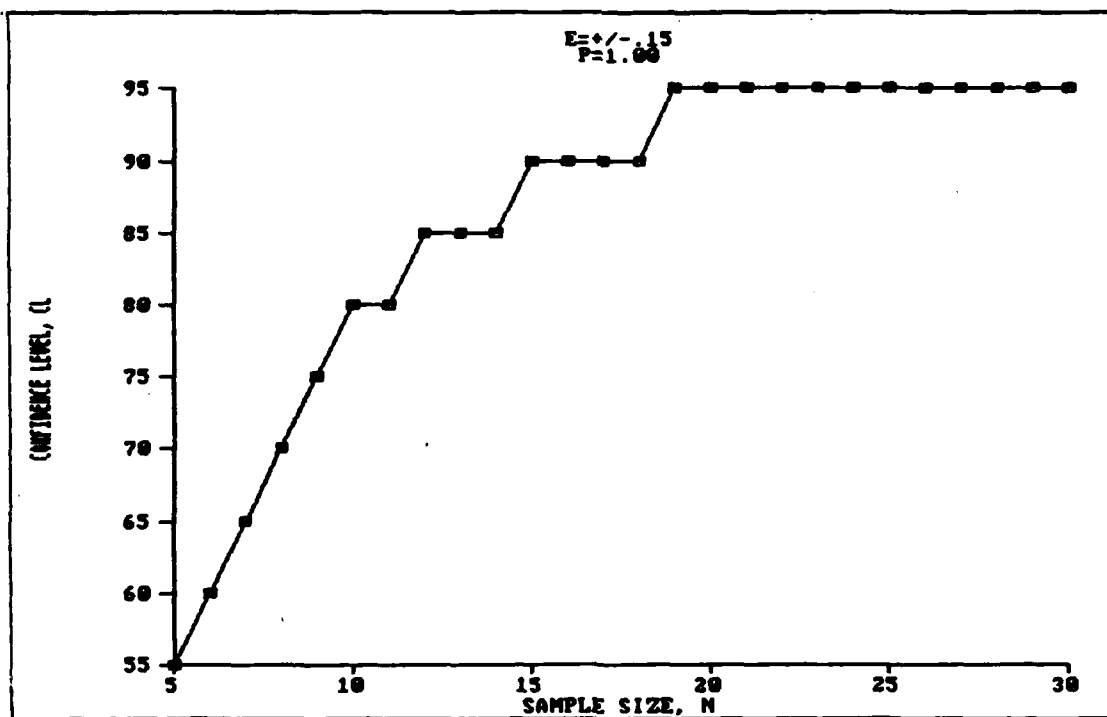


Figure 10. $E = \pm .15$ $P = 1.00$ $N = 30$

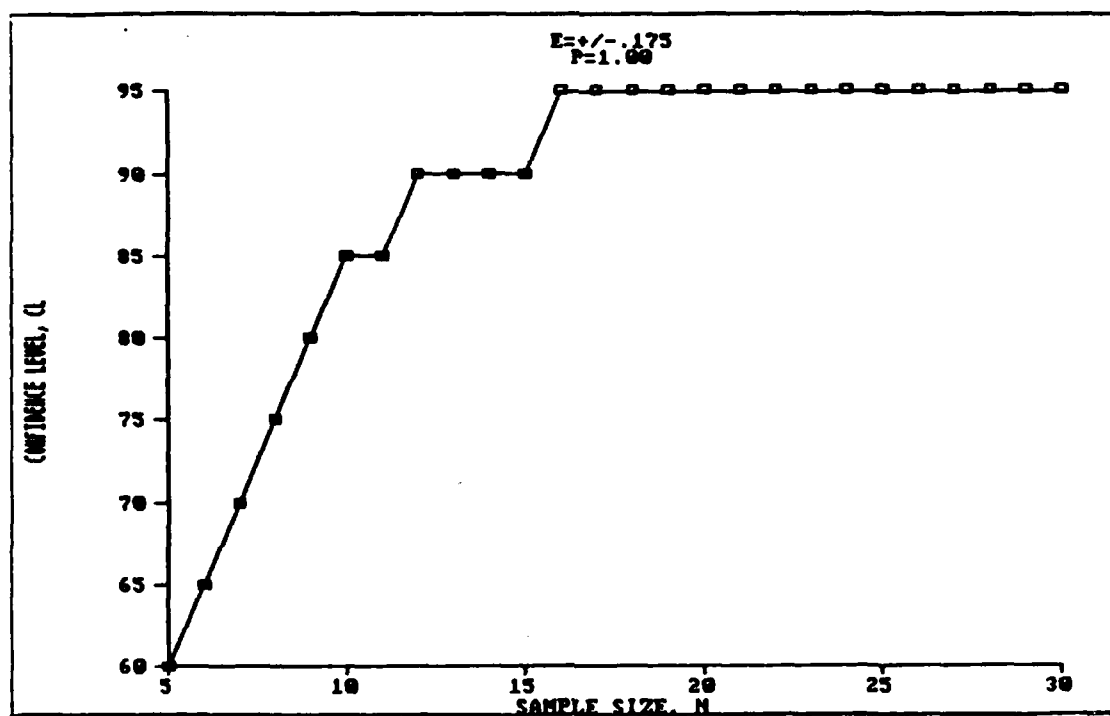


Figure 11. $E = \pm .175$ $P = 1.00$ $N = 30$

N = 11 to 30. As the sample size increases, the gains in confidence level taper off and eventually reach a point where gains in confidence for increasing sample sizes are very small and require too large of a sample size to be of use in this study. For sample sizes below N = 10, there is a 5% increase in confidence for each increase of 1 in sample size. In other words, there is a significant increase in confidence for the inspection of 4 engines versus 5 engines or 7 engines versus 9 engines. There is definitely enough to warrant careful consideration by program management.

While each proportion does not have such clearly defined slope changes as seen in the above graphs for $P=1.00$, each proportion follows this pattern of confidence level gains tapering off as the sample size increases past 20. This is seen in Figures 12 and 13.

As already stated in this research, studies have shown that humans do not accurately intuitively predict the relation of sampling variance to sample size (2:248). If one engine in an inspection of 10 fails inspection (90% pass), it is not the same statistically as 10 engines failing in an inspection of 100. Therefore, general assumptions made by engineering or management that inspecting 5 engines will not be statistically any more worthwhile than inspecting 4 are not true; in reality, management should realize that each additional inspection adds significantly to the amount of confidence that can be

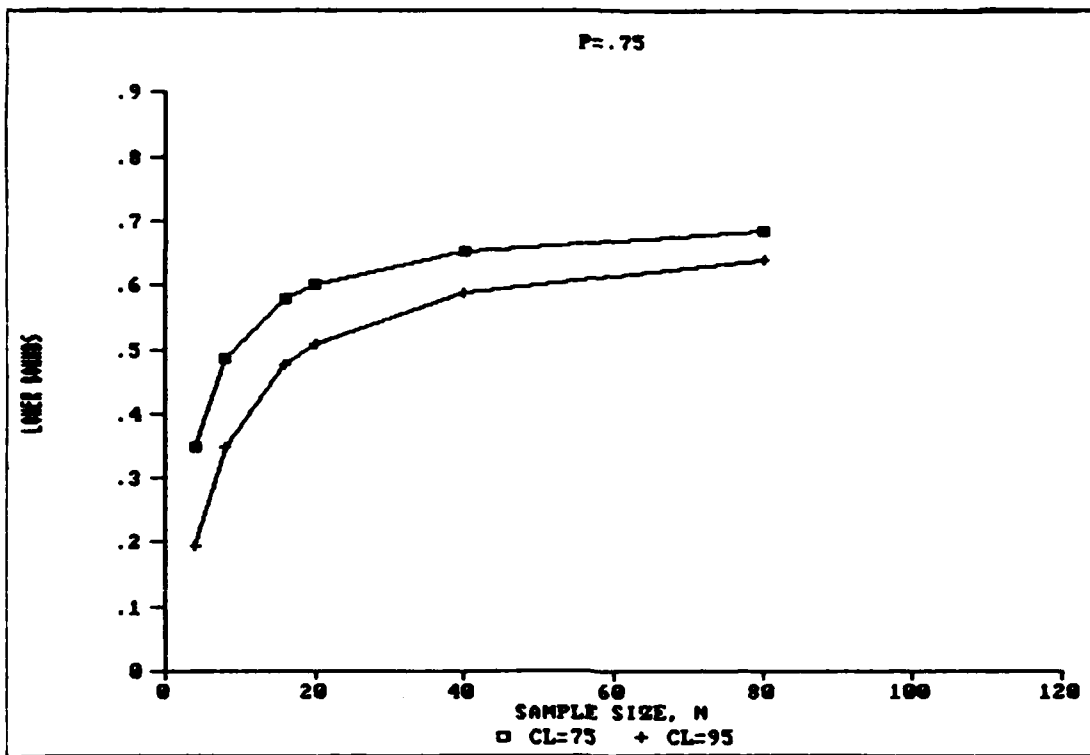


Figure 12. $P = .75$

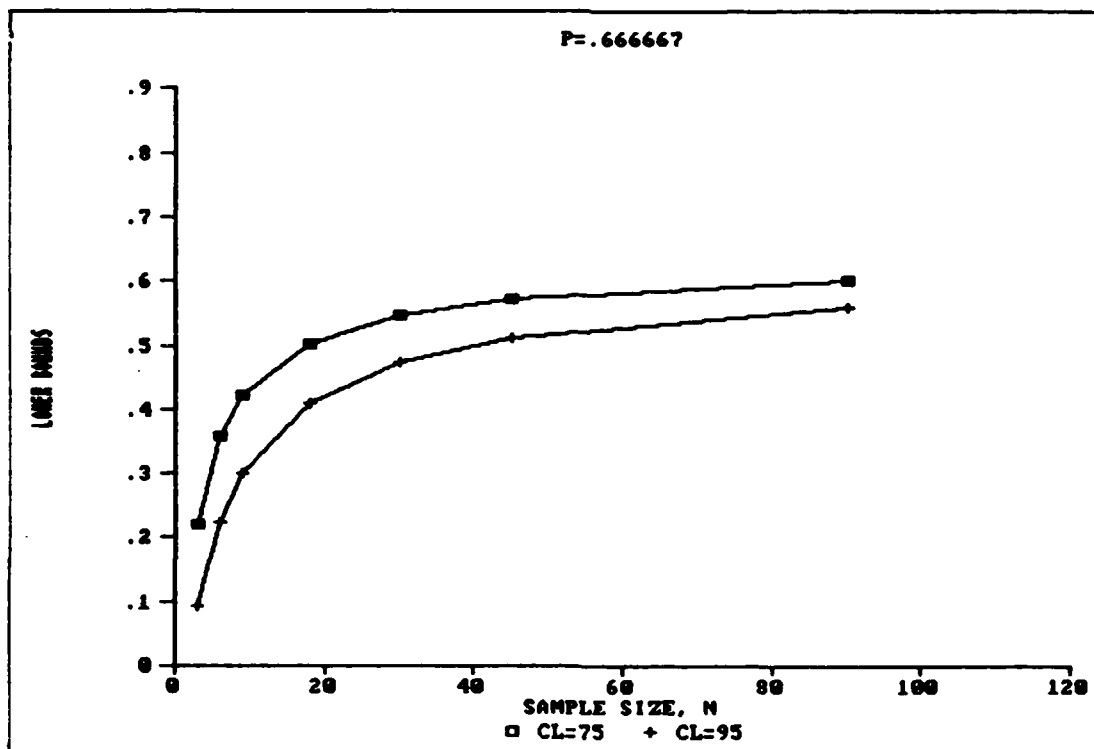


Figure 13. $P = .6666667$

placed in generalizing to the entire fleet based on the ACI inspections.

Summary Graphs

Presented in Chapter V are summary graphs which group the cases, (a case consisting of a specific N, Y, and C.L.), which meet each error range criteria and meet specified proportion criteria which is preset by the manager. For example, a manager who sets the criteria that 90% of the ACI engines must pass inspection before the inspection interval can be extended and wants to estimate the fleet proportion within 10% accuracy ($E = \pm .10$) would look to the 'Proportion Range $.9 \leq P < .95$ ' graph and the $E = \pm .1$ line to see what sample size gives the confidence level desired. Those summary graphs are based on the 18 graphs in Appendix C, then grouped by proportion ranges. Also presented in Chapter V will be an example for users to follow to ensure proper use of the summary graphs.

V. Recommendations and Conclusions

Implications as a Management Tool

The following six summary graphs (backed up by the data tables in Appendix B) present a model which managers can apply to any LTF/ACI program to determine appropriate sample sizes given certain preset constraints. More specifically, these graphs show required sample sizes to ensure varying confidence levels for varying levels of an acceptable number of components/engines that pass inspection and within specified error limits.

Given the cost and logistical constraints associated with real-world inspection programs, the major value of this research lies in its comparison capabilities. In other words, when logistical problems occur that force program management to consider reducing the number of engines/components to be inspected, these graphs provide a measure of the loss in prediction ability associated with fewer inspections. Managers can then make a trade-off analysis to decide whether it is actually worth reducing the number of inspections or, instead, find another means to solve the logistical problems.

Because the nature of ACIs is to project what will happen in the rest of the fleet, reducing the number of ACI inspections when that number is already low must be carefully considered first. Conflicts arise because while

the ACI inspections are held up due to lack of spares or other problems, the remainder of the fleet is approaching that set ACI inspection interval. If the ACIs are not completed on time, or if enough ACIs are not completed as required, the manager faces the decision to continue flying past that inspection interval based on incomplete or insubstantial ACI information, or to begin replacing the questionable components as spare parts allow, then eventually grounding aircraft that reach the interval without spare parts being available. General assumptions made by engineering or management that inspecting five engines will not be statistically any more worthwhile than inspecting four are based on faulty human intuition of statistics. Management must realize that each additional inspection adds significantly to the amount of confidence that can be placed in generalizing to the entire fleet based on the ACI inspections. This study allows the manager to determine the risk or decrease in confidence that is associated with a decrease in sample size or with an initial suboptimum sample size. The manager can then weigh the risks of inaccurately projecting trends against the rest of the fleet which could lead to safety or planning problems later with the problems caused by delaying ACIs or not reducing the number of inspections.

The discreteness effect previously discussed in Chapter IV is very noticeable in these summary graphs. Because proportions are defined as the number of successes, Y , per

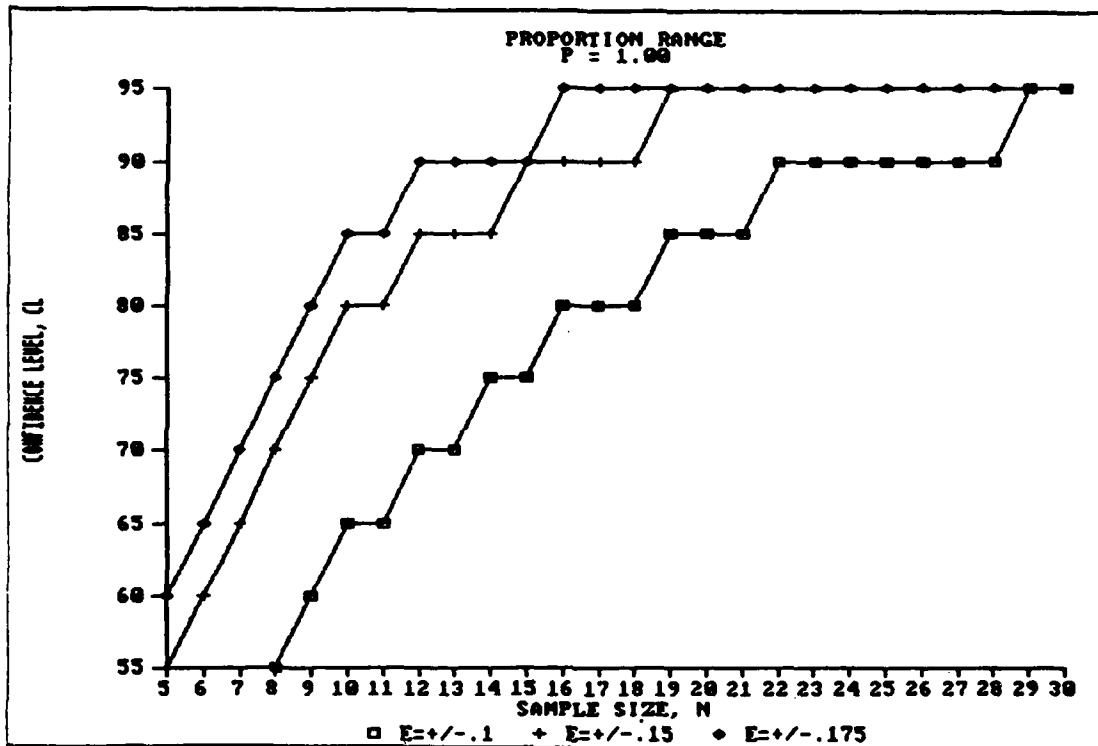


Figure 14. Summary Graph $P = 1.00$

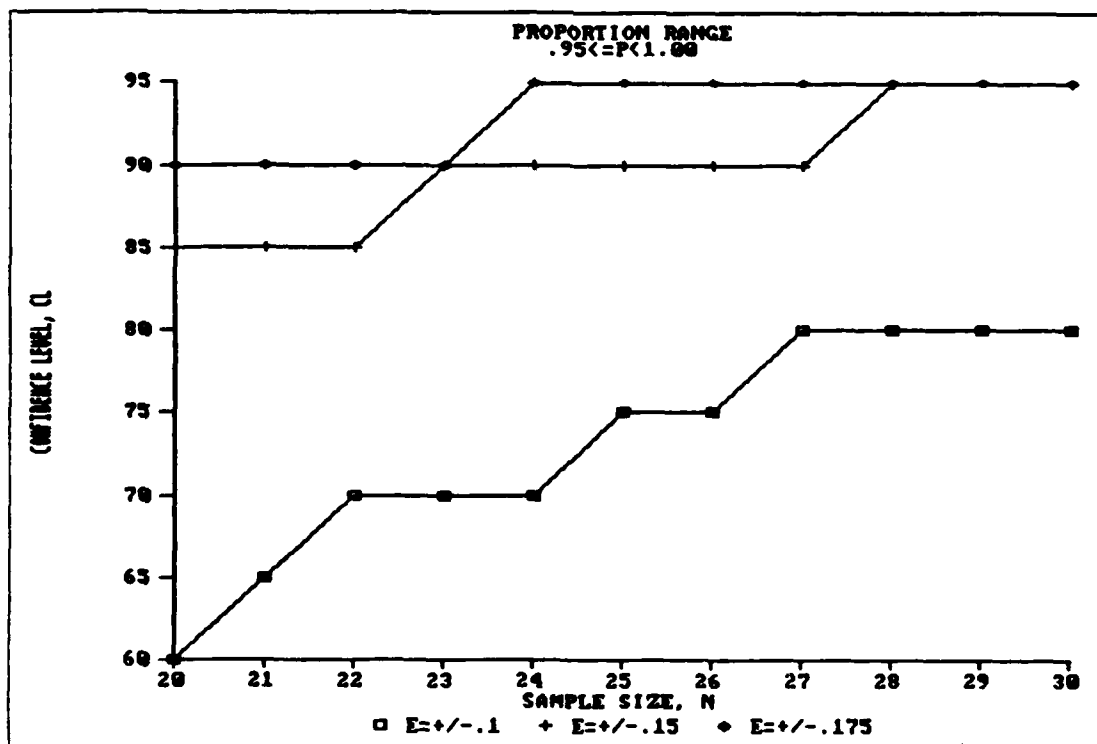


Figure 15. Summary Graph $.95 \leq P < 1.00$

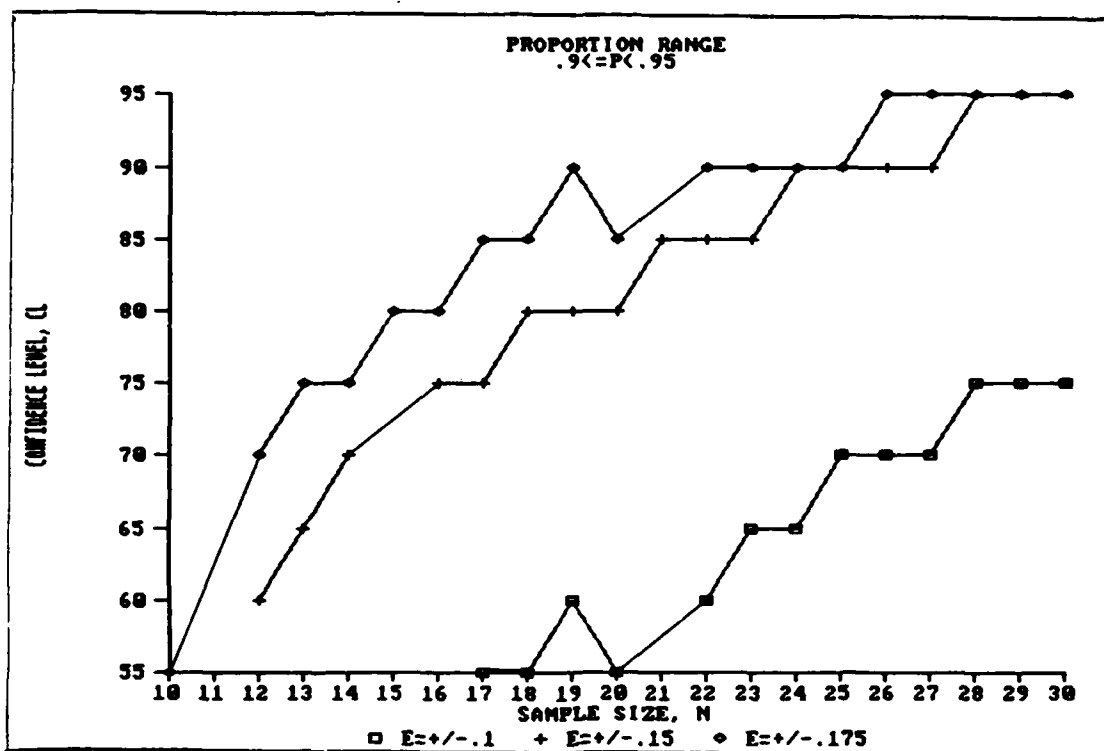


Figure 16. Summary Graph $.9 \leq P < .95$

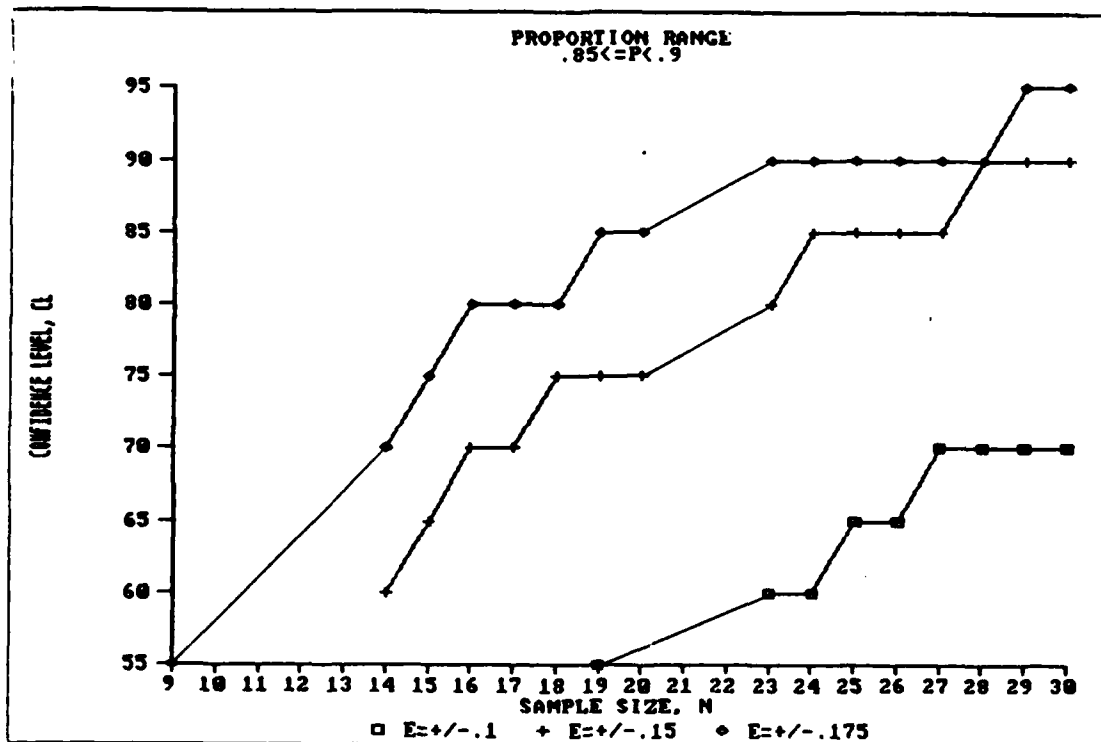


Figure 17. Summary Graph $.85 \leq P < .9$

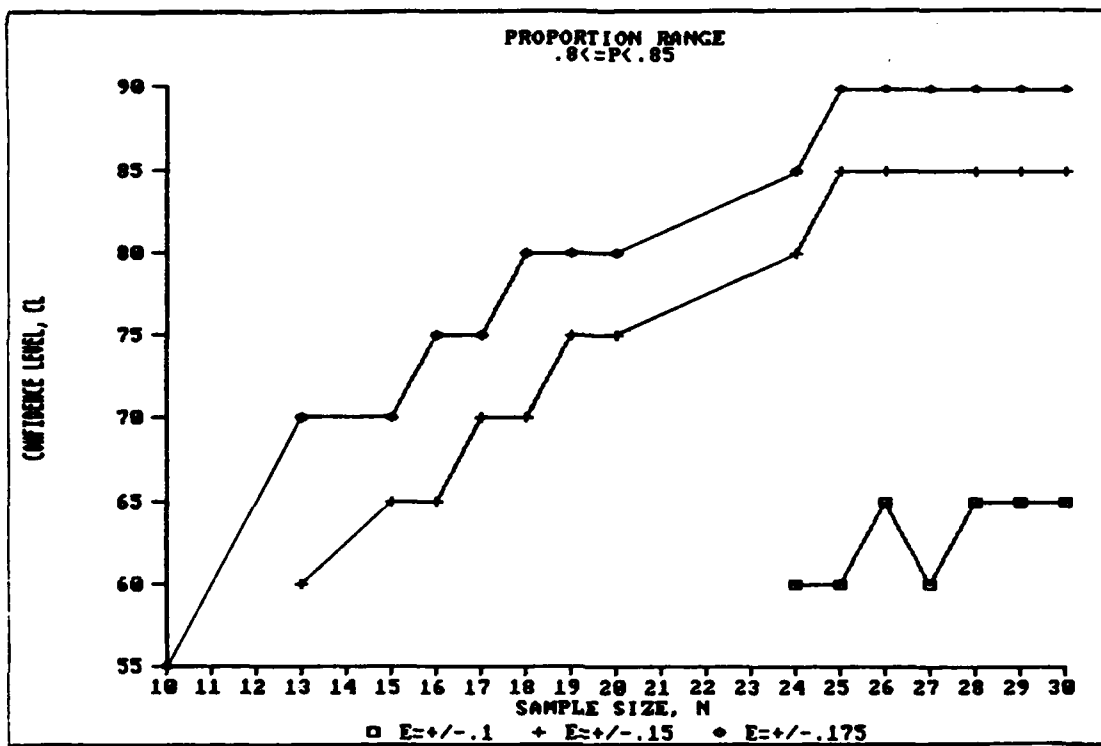


Figure 18. Summary Graph $.8 \leq P < .85$

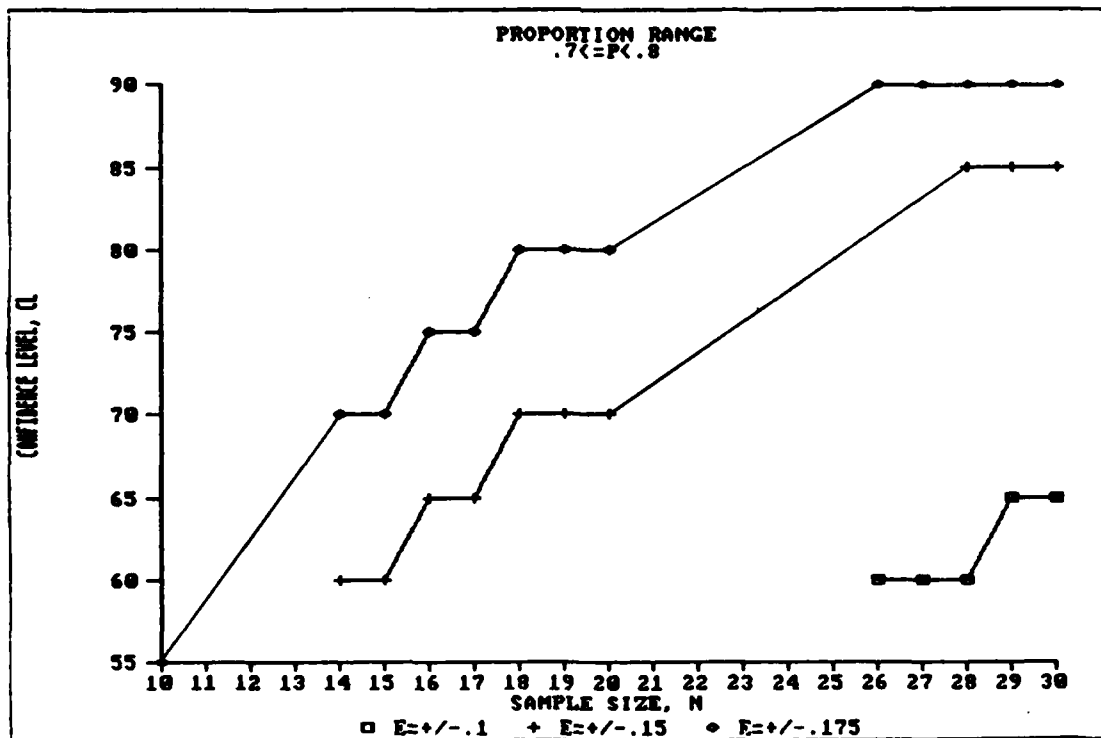


Figure 19. Summary Graph $.7 \leq P < .8$

sample size, n , the range of possible proportions is not continuous. For example, a sample size of 3 can only have 1, 2, or 3 successes corresponding to proportions of .33, .667, and 1.00. A sample size of 4 can only have 1, 2, 3, or 4 successes, corresponding to proportions of .25, .50, .75, and 1.00. Therefore, the range of proportions is not continuous and these summary graphs should not contain the lines drawn between data points. The lines, however, enhance the reader's ability to determine the change in slope as the sample size increases.

This discreteness effect is the reason that there are unusual "dips" in the summary graphs. The dips, for example in the $E=\pm .1$ graph in the range $.8 \leq P < .85$, are due to the different proportions of successes for sample sizes of 26, 27, and 28. At $N = 26$, the proportion of successes that falls within the $.8 \leq P < .85$ range is .8461538 ($22/26$); at $N = 27$, the proportion is .8148148 ($22/27$); at $N = 28$, the proportion is .8214286 ($23/28$). The proportion at $N = 26$ is high enough to attain 65% confidence, while the highest proportion at $N = 27$ in the same $.8 \leq P < .85$ range is only able to attain 60% confidence. The proportion at $N = 28$ and $Y = 23$ is then high enough again to attain 65%.

Practical Application

Again, the purpose of this study is to show the gains (or losses) associated with inspecting X more (or less) engines in an ACI program by showing how much confidence can

be gained (or lost) with that increase or decrease in inspection. These gains (losses) will provide the manager with a measurement tool against which to measure logistical, engineering, and cost conflicts in choosing the proper number of engines to inspect. Application of this model can best be shown through examples. Consider a manager in the planning stages of a LTF/ACI program. The manager decides that since his program involves a single-engine aircraft, he would like to maximize the degree of confidence he has that 100% of the engines in the fleet will pass inspection with a maximum allowable error of $\pm 10\%$. He goes to the summary graph for $P=1.00$ and finds the curve for $E=\pm .1$. From here he learns that he can attain only 65% confidence with a sample of 10 engines. If he has the resources, he could increase the sample of engines to 12 and receive 70% confidence, to 14 for 75% confidence, to 16 for 80% confidence, to 19 for 85% confidence, etc.

Another example shows the more probable use of this research, determining the loss in confidence associated with a smaller sample size. Consider a manager who is trying to decide whether he should reduce the sample size due to spare parts problems. Currently, he has a sample size of 10 which he is considering reducing to 8. If he set his maximum allowable error at $E=\pm .15$, then reducing the sample size from 10 to 8 means he loses 10% confidence (from 80 to 70%) in his estimate of the proportion ($P=1.00$) of the fleet engines that will also pass the ACI inspection. If he set

his maximum allowable error at $E = \pm .10$ (10%), he would still lose 10% confidence that his estimate of fleet engines is correct, however, this time it will decrease from 65 to 55%.

Where before managers had no real estimate of the loss in value of their ACI programs when reductions were being considered, they now have a measurement tool to use to weigh the various options. While this may be only a portion of the managers overall decision, it is meant to quantify at least part of that decision-making process.

Recommendations for Follow-On Study

As mentioned, this research represents only a portion of the decision-making process managers employ to determine sample sizes for LTF/ACI programs. Many other issues are involved to include cost and logistical constraints. Logistical constraints can vary from a lack of spare parts, to a deficiency in maintenance crews available, to contractor support problems. Up-front planning is the most vital part of a successful LTF/ACI program. There are many areas of research that could improve this up-front planning, such as a scheduling model for spare parts requirements at different ACI intervals based on past programs. This section will concentrate, however, on follow-on research directly integrable with this thesis.

One future area of research would be to develop a cost trade-off analysis that would present the cost of various

sample size ACI programs and trade those costs off against the savings inherent in sampling engines and finding problems before they become critical. Examples of those costs would include the actual manhours of labor to do the inspections, the costs of parts like seals that must be replaced each time components are removed, and the cost of contractor support since contractors and subcontractors usually accomplish the initial ACIs. Examples of the savings include the savings associated with inspecting and replacing parts that are near failure before they actually fail, thus preventing nearby components from possible damage by such failure or possibly saving the entire aircraft if the part is critical. Failure Modes and Effects Analyses could be used to help generate these savings.

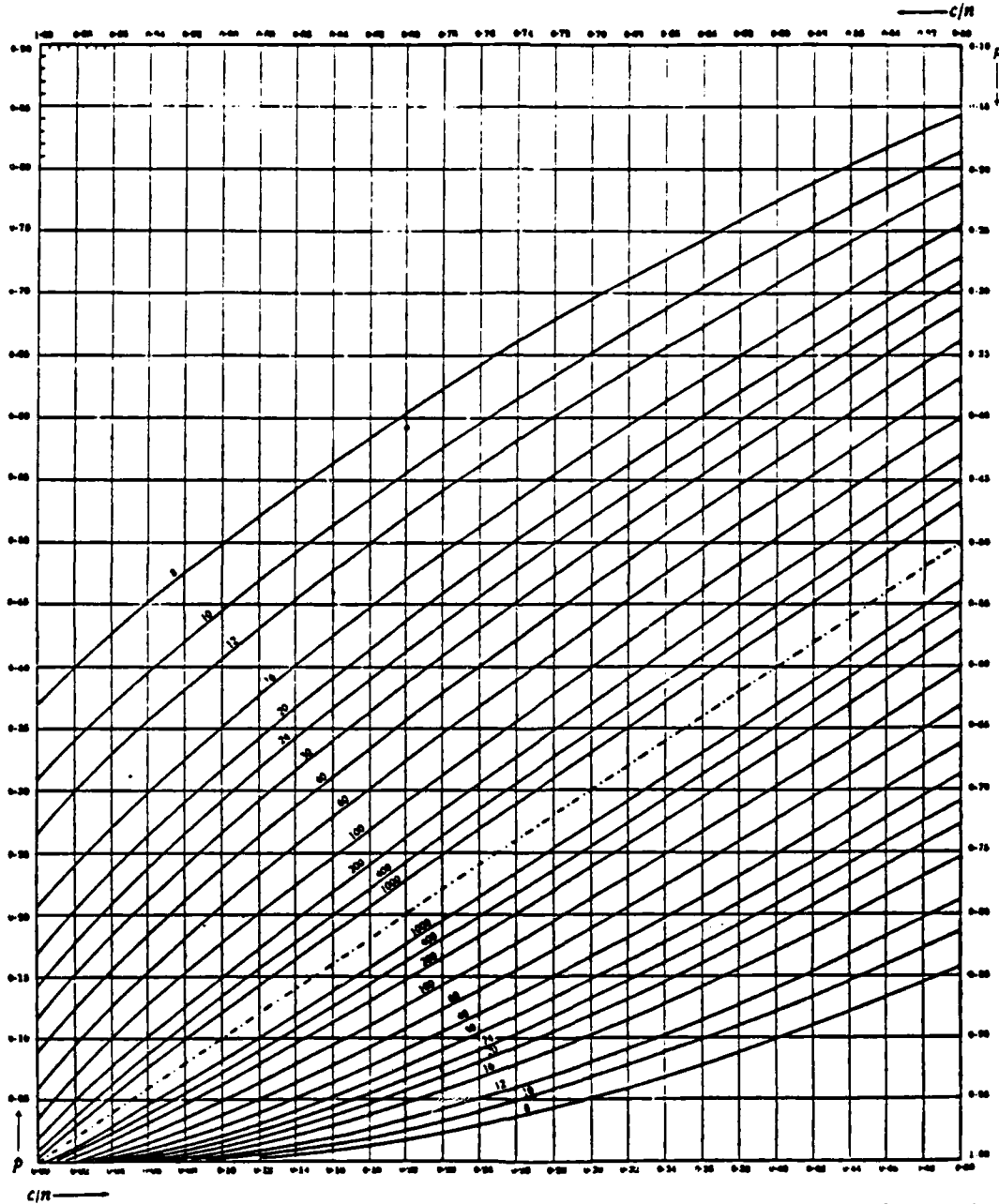
Another area of future research would be to analyze past ACI programs to find what problem areas were actually discovered during the ACIs, then do a cost analysis showing the cost or savings associated with finding those specific problems early in the program. This is in contrast to the above suggestion of doing a generic cost analysis for any general problem that might be found in ACIs. This approach would limit the study to something more manageable for an eighteen month thesis effort.

Finally, research should be done by the Air Force over an extended period of time comparing the ACI results to the fleet's maintenance records after a substantial number of years operation. The study should analyze the benefit of

the initial ACIs in forecasting the fleet's maintenance over the years. Eventually the study should include several varied engine programs and should make recommendations for improvements based on the findings.

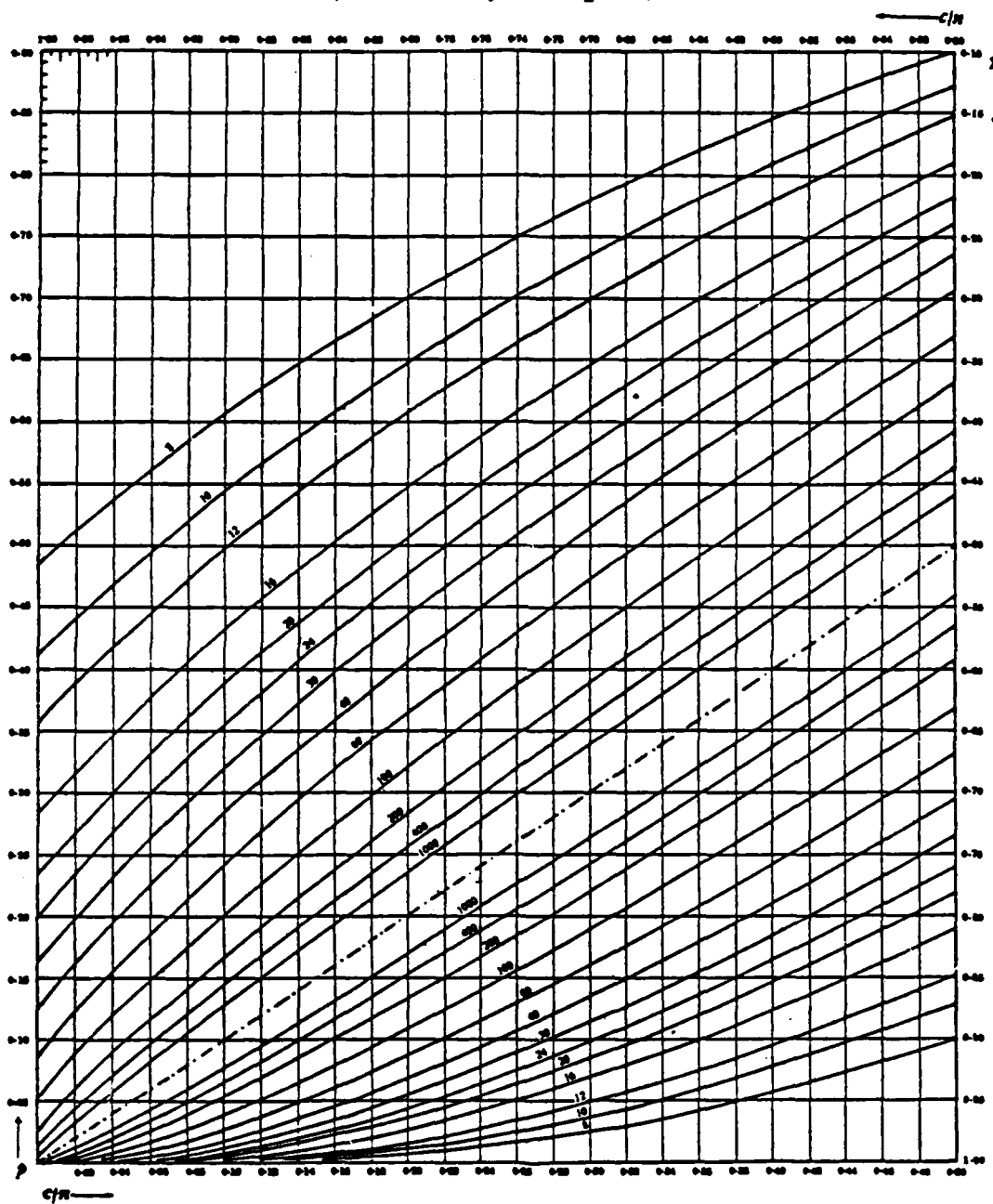
Appendix A: Pearson and Hartley Charts

Chart providing confidence limits for p in binomial sampling, given a sample fraction c/n .
Confidence coefficient, $1 - 2\alpha = 0.95$.



(9:204)

(continued). Confidence coefficient, $1 - 2\alpha = 0.99$.



The numbers printed along the curves indicate the sample size n .

Note: the process of reading from the curves can be simplified with the help of the right-angled corner of a loose sheet of paper or thin card, along the edges of which are marked off the scales shown in the top left-hand corner of each Chart.

(9:205)

Appendix B: Data Tables for $E=+/- .1$, $E=+/- .15$, and $E=+/- .175$

P = 1.00 RANGE		E=+/- .1				
N	Y	CL	PROP	UPPER	LOWER	
8	8	55	1		.9050062	
9	9	60	1		.9032011	
10	10	65	1		.9003406	
11	11	65	1		.9089744	
12	12	70	1		.9045379	
13	13	70	1		.9115459	
14	14	75	1		.9057237	
15	15	75	1		.9117225	
16	16	80	1		.9043038	
17	17	80	1		.9096705	
18	18	80	1		.9144676	
19	19	85	1		.9049746	
20	20	85	1		.9095039	
21	21	85	1		.9136214	
22	22	90	1		.9006281	
23	23	90	1		.9047358	
24	24	90	1		.9085176	
25	25	90	1		.9120109	
26	26	90	1		.9152473	
27	27	90	1		.9182543	
28	28	90	1		.9210553	
29	29	95	1		.9018554	
30	30	95	1		.9049661	

E=+/- .1					
.95<=P<1.00 RANGE					
N	Y	CL	PROP	UPPER	LOWER
20	19	55	.95	.9873364	.8645598
20	19	60	.95	.9889049	.8575677
21	20	55	.952381	.9879358	.8707267
21	20	60	.952381	.9894304	.8640275
21	20	65	.952381	.9908812	.8566017
22	21	55	.9545455	.988481	.8763571
22	21	60	.9545455	.9899084	.8699274
22	21	65	.9545455	.991294	.8627978
22	21	70	.9545455	.99264	.8547486
23	22	55	.9565217	.9889791	.8815178
23	22	60	.9565217	.990345	.8753373
23	22	65	.9565217	.9916709	.8684812
23	22	70	.9565217	.9929589	.8607382
24	23	55	.9583333	.9894358	.8862652
24	23	60	.9583333	.9907456	.8803154
24	23	65	.9583333	.9920166	.8737131
24	23	70	.9583333	.9932512	.866254
25	24	55	.96	.9898562	.8906474
25	24	60	.96	.991114	.8849117
25	24	65	.96	.9923346	.8785451
25	24	70	.96	.9935204	.87135
25	24	75	.96	.994673	.8630412
26	25	55	.9615385	.9902445	.8947046
26	25	60	.9615385	.9914544	.8891681
26	25	65	.9615385	.9926284	.8830212
26	25	70	.9615385	.9937688	.8760724
26	25	75	.9615385	.9948773	.8680449
27	26	55	.962963	.9906041	.8984716
27	26	60	.962963	.9917696	.8931212
27	26	65	.962963	.9929005	.8871794
27	26	70	.962963	.9939989	.8804606
27	26	75	.962963	.9950666	.8726965
27	26	80	.962963	.9961054	.8634313
28	27	55	.9642857	.9909382	.9019785
28	27	60	.9642857	.9920623	.8968022
28	27	65	.9642857	.9931531	.8910524
28	27	70	.9642857	.9942126	.8845491
28	27	75	.9642857	.9952424	.8770316
28	27	80	.9642857	.9962442	.8680578
29	28	55	.9655172	.9912493	.9052514
29	28	60	.9655172	.9923349	.9002383
29	28	65	.9655172	.9933885	.8946684
29	28	70	.9655172	.9944116	.8883674
29	28	75	.9655172	.9954061	.8810815
29	28	80	.9655172	.9963734	.8723813
30	29	55	.9666667	.9915397	.9083129
30	29	60	.9666667	.9925895	.9034531
30	29	65	.9666667	.9936082	.8980523
30	29	70	.9666667	.9945973	.8919414
30	29	75	.9666667	.9955589	.8848735
30	29	80	.9666667	.9964942	.8764309

E=+/- .1

.9<=P<.95 RANGE

N	Y	CL	PROP	UPPER	LOWER
17	16	55	.9411765	.9851184	.841946
18	17	55	.9444444	.9859392	.8502776
19	18	55	.9473684	.9866744	.8577758
19	18	60	.9473684	.9883244	.8504644
20	18	55	.9	.9552136	.8059403
22	20	55	.9090909	.9592967	.8227261
22	20	60	.9090909	.9623695	.8153948
23	21	55	.9130435	.9610712	.8300768
23	21	60	.9130435	.9640125	.8230164
23	21	65	.9130435	.9670071	.8152428
24	22	55	.9166667	.9626974	.8368431
24	22	60	.9166667	.9655182	.8300347
24	22	65	.9166667	.9683894	.8225354
25	23	55	.92	.9641931	.8430919
25	23	60	.92	.9669028	.8365184
25	23	65	.92	.9696605	.8292753
25	23	70	.92	.9724909	.8211557
26	24	55	.9230769	.9655736	.8488804
26	24	60	.9230769	.9681805	.8425263
26	24	65	.9230769	.9708334	.8355228
26	24	70	.9230769	.9735561	.8276689
27	25	55	.9259259	.9668516	.8542574
27	25	60	.9259259	.9693631	.8481088
27	25	65	.9259259	.9719188	.8413299
27	25	70	.9259259	.9745416	.8337251
28	26	55	.9285714	.968038	.8592653
28	26	60	.9285714	.9704611	.8533097
28	26	65	.9285714	.9729265	.8467415
28	26	70	.9285714	.9754563	.839371
28	26	75	.9285714	.9780801	.8309191
29	27	55	.9310345	.9691424	.8636408
29	27	60	.9310345	.9714829	.8581666
29	27	65	.9310345	.9738643	.8517966
29	27	70	.9310345	.9763076	.8446466
29	27	75	.9310345	.9788412	.8364448
30	27	55	.9	.9452416	.8299608
30	27	60	.9	.9484166	.8238026
30	27	65	.9	.9516902	.8170388
30	27	70	.9	.9551298	.8094851
30	27	75	.9	.958764	.8008573
30	28	55	.9333333	.9701732	.8683161
30	28	60	.9333333	.9724365	.8627124
30	28	65	.9333333	.9747393	.8565293
30	28	70	.9333333	.9771016	.8495871
30	28	75	.9333333	.9795513	.8416212

.85<=P<.9 RANGE		E=+/- .1			
M	Y	CL	PROP	UPPER	LOWER
19	17	55	.8947368	.9528483	.7962993
23	20	55	.8695652	.9284269	.7808628
23	20	60	.8695652	.9325419	.7731778
24	21	55	.875	.9314348	.7895401
24	21	60	.875	.9353829	.782116
25	22	55	.88	.9342002	.7975578
25	22	60	.88	.9379941	.7903784
25	22	65	.88	.9419202	.782506
26	23	55	.8846154	.936751	.8049882
26	23	60	.8846154	.9404027	.7980385
26	23	65	.8846154	.9441804	.7904149
27	23	55	.8518519	.9094182	.7707471
27	23	60	.8518519	.9137516	.7635656
27	23	65	.8518519	.9182737	.755713
27	24	55	.8888889	.9391114	.8118935
27	24	60	.8888889	.9426309	.8051596
27	24	65	.8888889	.9462716	.7977701
27	24	70	.8888889	.9500774	.7895255
28	24	55	.8571429	.9126915	.7785545
28	24	60	.8571429	.9168751	.7715806
28	24	65	.8571429	.9212406	.7639523
28	25	55	.8928571	.9413018	.8183272
28	25	60	.8928571	.9446984	.8117966
28	25	65	.8928571	.9482115	.8046277
28	25	70	.8928571	.9518834	.7966265
29	25	55	.862069	.915736	.7858486
29	25	60	.862069	.9197802	.7790714
29	25	65	.862069	.9239994	.7716555
29	25	70	.862069	.928452	.7634057
29	26	55	.8965517	.9433401	.8243361
29	26	60	.8965517	.9466221	.817997
29	26	65	.8965517	.950016	.8110365
29	26	70	.8965517	.953563	.8032652
30	26	55	.8666667	.9185756	.7926786
30	26	60	.8666667	.9224892	.7860877
30	26	65	.8666667	.9265717	.7788733
30	26	70	.8666667	.9308791	.7708449

E=+/- .1

.8<=P<.85 RANGE

N	Y	CL	PROP	UPPER	LOWER
24	20	55	.8333333	.8079382	.7430438
24	20	60	.8333333	.9027913	.7357632
25	20	55	.8	.8685708	.7101634
25	20	60	.8	.8730664	.7021872
25	21	55	.84	.9020754	.7533611
25	21	60	.84	.9067418	.7457273
26	21	55	.8076923	.8737135	.7207024
26	21	60	.8076923	.8789115	.7129565
26	22	55	.8461538	.9058901	.7623708
26	22	60	.8461538	.9103834	.7540606
26	22	65	.8461538	.9150742	.74688
27	22	55	.8148148	.8784682	.7305045
27	22	60	.8148148	.8834635	.7229772
28	23	55	.8214286	.8828779	.7396441
28	23	60	.8214286	.8877228	.7323245
28	23	65	.8214286	.8928077	.7243403
29	24	55	.8275862	.8869784	.7481861
29	24	60	.8275862	.8916639	.7410638
29	24	65	.8275862	.8965809	.733292
30	24	55	.8	.8622189	.720322
30	24	60	.8	.8672913	.7131145
30	24	65	.8	.8726362	.7052647
30	25	55	.8333333	.8908008	.7561868
30	25	60	.8333333	.8953373	.7492526
30	25	65	.8333333	.9000968	.7416826

E=+/- .1

.7<=P<.8 RANGE			CL	PROP	UPPER	LOWER
N	Y					
26	20	60	.7692308	.8463675	.6717924	
27	20	55	.7407407	.8139907	.6520733	
27	20	60	.7407407	.8200931	.6440847	
27	21	55	.7777778	.8465958	.690984	
27	21	60	.7777778	.8521947	.6831952	
28	20	55	.7142857	.788817	.6266308	
28	20	60	.7142857	.7951477	.6186911	
28	21	55		.75	.8207916	.6637771
28	21	60		.75	.8266944	.6559846
28	22	55	.7857143	.8521834	.7014211	
28	22	60	.7857143	.8575952	.693833	
29	21	55	.7241379	.7962918	.6387388	
29	21	60	.7241379	.8024256	.630979	
29	22	55	.7586207	.8271116	.6747231	
29	22	60	.7586207	.8328273	.6671195	
29	22	65	.7586207	.8388714	.6588566	
29	23	55	.7931034	.8573779	.7111793	
29	23	60	.7931034	.8626146	.7037858	
29	23	65	.7931034	.8681335	.6957365	
30	21	55		.7	.7730511	.6156018
30	21	60		.7	.7793596	.607898
30	22	55	.7333333	.8032539	.6500907	
30	22	60	.7333333	.809203	.6425052	
30	22	65	.7333333	.8155078	.6342736	
30	23	55	.7666667	.8330003	.6849796	
30	23	60	.7666667	.8385401	.6775601	
30	23	65	.7666667	.8443967	.6694906	

P = 1.00 RANGE		E=+/- .15		PROP	UPPER	LOWER
N	Y	CL				
5	5	55		1		.8523982
6	6	60		1		.8583742
7	7	65		1		.8607298
8	8	70		1		.8602806
9	9	75		1		.857244
10	10	80		1		.8513399
11	11	80		1		.8638877
12	12	85		1		.8537701
13	13	85		1		.8642161
14	14	85		1		.8732716
15	15	90		1		.8576959
16	16	90		1		.8659643
17	17	90		1		.8733262
18	18	90		1		.8799225
19	19	95		1		.8541314
20	20	95		1		.8606917
21	21	95		1		.8670541
22	22	95		1		.8726946
23	23	95		1		.8778766
24	24	95		1		.8826538
25	25	95		1		.8870719
26	26	95		1		.8911697
27	27	95		1		.8949808
28	28	95		1		.8985343
29	29	95		1		.9018554
30	30	95		1		.9049661

.95<=P<1.00		E=+/- .15				
N	RANGE	Y	CL	PROP	UPPER	LOWER
20	19	55	.95	.9873364	.8645598	
20	19	60	.95	.9889049	.8575677	
20	19	65	.95	.9904275	.8498204	
20	19	70	.95	.9919071	.8410817	
20	19	75	.95	.9933456	.8310133	
20	19	80	.95	.9947459	.8190396	
20	19	85	.95	.9961095	.804109	
21	20	55	.952381	.9879358	.8707267	
21	20	60	.952381	.9894304	.8640275	
21	20	65	.952381	.9908812	.8566017	
21	20	70	.952381	.9922909	.8482217	
21	20	75	.952381	.9936616	.8385613	
21	20	80	.952381	.9949954	.8270656	
21	20	85	.952381	.9962945	.8127197	
22	21	55	.9545455	.988481	.8763571	
22	21	60	.9545455	.9899084	.8699274	
22	21	65	.9545455	.991294	.8627978	
22	21	70	.9545455	.99264	.8547486	
22	21	75	.9545455	.9939488	.8454651	
22	21	80	.9545455	.9952222	.8344114	
22	21	85	.9545455	.9964626	.8206076	
23	22	55	.9565217	.9889791	.8815178	
23	22	60	.9565217	.990345	.8753373	
23	22	65	.9565217	.9916709	.8684812	
23	22	70	.9565217	.9929589	.8607382	
23	22	75	.9565217	.9942111	.8518036	
23	22	80	.9565217	.9954296	.8411598	
23	22	85	.9565217	.9966161	.8278594	
23	22	90	.9565217	.9977723	.8097961	
24	23	55	.9583333	.9894358	.8862652	
24	23	60	.9583333	.9907456	.8803154	
24	23	65	.9583333	.9920166	.8737131	
24	23	70	.9583333	.9932512	.866254	
24	23	75	.9583333	.9944516	.8576434	
24	23	80	.9583333	.9956196	.8473807	
24	23	85	.9583333	.9967569	.8345432	
24	23	90	.9583333	.9978651	.8171076	
25	24	55	.96	.9898562	.8906474	
25	24	60	.96	.991114	.8849117	
25	24	65	.96	.9923346	.8785451	
25	24	70	.96	.9935204	.87135	
25	24	75	.96	.994673	.8630412	
25	24	80	.96	.9957945	.8531336	
25	24	85	.96	.9968864	.8407333	
25	24	90	.96	.9979504	.8238793	
26	25	55	.9615385	.9902445	.8947046	
26	25	60	.9615385	.9914544	.8891681	
26	25	65	.9615385	.9926284	.8830212	
26	25	70	.9615385	.9937688	.8760724	
26	25	75	.9615385	.9948773	.8680449	

.95<=P<1.00		RANGE		E=+/- .15	
N	Y	CL	PROP	UPPER	LOWER
25	25	80	.9615385	.9959559	.8584692
26	25	85	.9615385	.9970059	.8464779
26	25	90	.9615385	.9980291	.8301688
27	26	55	.962963	.9906041	.8984716
27	26	60	.962963	.9917696	.8931212
27	26	65	.962963	.9929005	.8871794
27	26	70	.962963	.9939989	.8804606
27	26	75	.962963	.9950666	.8726966
27	26	80	.962963	.9961054	.8634313
27	26	85	.962963	.9971167	.8518233
27	26	90	.962963	.9981021	.8360256
28	27	55	.9642857	.9909382	.9019785
28	27	60	.9642857	.9920623	.8968022
28	27	65	.9642857	.9931531	.8910524
28	27	70	.9642857	.9942126	.8845491
28	27	75	.9642857	.9952424	.8770316
28	27	80	.9642857	.9962442	.8680579
28	27	85	.9642857	.9972195	.8568096
28	27	90	.9642857	.9981698	.8414929
28	27	95	.9642857	.9990962	.8165248
29	28	55	.9655172	.9912493	.9052514
29	28	60	.9655172	.9923349	.9002383
29	28	65	.9655172	.9933885	.8946684
29	28	70	.9655172	.9944116	.8883674
29	28	75	.9655172	.9954061	.8810815
29	28	80	.9655172	.9963734	.8723813
29	28	85	.9655172	.9973153	.8614717
29	28	90	.9655172	.9982328	.846608
29	28	95	.9655172	.9991274	.8223583
30	29	55	.9666667	.9915397	.9083129
30	29	60	.9666667	.9925895	.9034531
30	29	65	.9666667	.9936082	.8980623
30	29	70	.9666667	.9945973	.8919414
30	29	75	.9666667	.9955589	.8848735
30	29	80	.9666667	.9964942	.8764309
30	29	85	.9666667	.9974046	.8658404
30	29	90	.9666667	.9982917	.8514039
30	29	95	.9666667	.9991564	.8278335

E=+/- .15

.9<=P<.95 RANGE

N	Y	CL	PROP	UPPER	LOWER
13	12	55	.9230769	.980584	.7967273
13	12	60	.9230769	.9829817	.7866843
13	12	65	.9230769	.9853111	.7756054
14	13	55	.9285714	.9819584	.8102898
14	13	60	.9285714	.9841876	.8008313
14	13	65	.9285714	.9863532	.7903867
14	13	70	.9285714	.9884586	.7786645
15	14	55	.9333333	.9831509	.8221597
15	14	60	.9333333	.9852339	.8132233
15	14	65	.9333333	.9872571	.8033468
15	14	70	.9333333	.9892239	.7922516
16	15	55	.9375	.9841956	.8326345
16	15	60	.9375	.9861504	.8241669
16	15	65	.9375	.9880488	.8148017
16	15	70	.9375	.989894	.8042722
16	15	75	.9375	.9916889	.7921709
17	16	55	.9411765	.9851184	.841946
17	16	60	.9411765	.9869598	.8339016
17	16	65	.9411765	.9887478	.8249987
17	16	70	.9411765	.9904856	.8149814
17	16	75	.9411765	.992176	.8034594
18	17	55	.9444444	.9859392	.8502776
18	17	60	.9444444	.9876798	.8426168
18	17	65	.9444444	.9893696	.8341372
18	17	70	.9444444	.9910118	.8245825
18	17	75	.9444444	.992609	.8135881
18	17	80	.9444444	.9941638	.8005331
19	18	55	.9473684	.9866744	.8577758
19	18	60	.9473684	.9883244	.8504644
19	18	65	.9473684	.9899262	.8423672
19	18	70	.9473684	.9914829	.8332383
19	18	75	.9473684	.9929967	.8227268
19	18	80	.9473684	.9944701	.810235
20	18	55	.9	.9552136	.8059403
20	18	60	.9	.9585879	.7980025
20	18	65	.9	.9620249	.789275
20	18	70	.9	.9655552	.7795179
20	18	75	.9	.9692208	.7683666
20	18	80	.9	.9730858	.7552348
22	20	55	.9090909	.9592967	.8227261
22	20	60	.9090909	.9623695	.8153948
22	20	65	.9090909	.9654983	.8073266
22	20	70	.9090909	.9687108	.7982972
22	20	75	.9090909	.9720456	.7879631
22	20	80	.9090909	.9755802	.7757762
22	20	85	.9090909	.9793507	.760712
23	21	55	.9130435	.9610712	.8300768
23	21	60	.9130435	.9640125	.8230164
23	21	65	.9130435	.9670071	.8152428
23	21	70	.9130435	.9700814	.8065356
23	21	75	.9130435	.9732719	.7965721

.9<=P<.95 RANGE		E=+/- .15			
N	Y	CL	PROP	UPPER	LOWER
23	21	80	.9130435	.9786345	.7848108
23	21	85	.9130435	.9802598	.7702611
24	22	55	.9166667	.9628974	.8368431
24	22	60	.9166667	.9655182	.8300347
24	22	65	.9166667	.9683894	.8225354
24	22	70	.9166667	.9713368	.814132
24	22	75	.9166667	.9743952	.8045113
24	22	80	.9166667	.9776181	.793148
24	22	85	.9166667	.9810924	.7790806
25	23	55	.92	.9641931	.8430919
25	23	60	.92	.9669028	.8365184
25	23	65	.92	.9696605	.8292753
25	23	70	.92	.9724909	.8211557
25	23	75	.92	.9754279	.8118556
25	23	80	.92	.9785222	.8008651
25	23	85	.92	.9818576	.7872503
26	24	55	.9230769	.9655736	.8488804
26	24	60	.9230769	.9681805	.8425263
26	24	65	.9230769	.9708334	.8355228
26	24	70	.9230769	.9735561	.8276689
26	24	75	.9230769	.9763804	.8186694
26	24	80	.9230769	.979356	.8080288
26	24	85	.9230769	.982563	.7948395
26	24	90	.9230769	.9861576	.7771063
27	25	55	.9259259	.9668516	.8542574
27	25	60	.9259259	.9693631	.8481088
27	25	65	.9259259	.9719188	.8413299
27	25	70	.9259259	.9745416	.8337251
27	25	75	.9259259	.9772619	.825008
27	25	80	.9259259	.9801277	.8146963
27	25	85	.9259259	.9832156	.8019077
27	25	90	.9259259	.9866767	.7847001
28	26	55	.9285714	.968038	.8592653
28	26	60	.9285714	.9704611	.8533097
28	26	65	.9285714	.9729265	.8467415
28	26	70	.9285714	.9754563	.839371
28	26	75	.9285714	.9780801	.8309191
28	26	80	.9285714	.9808436	.8209171
28	26	85	.9285714	.9838212	.8085063
28	26	90	.9285714	.9871581	.7917953
29	27	55	.9310345	.9691424	.8639408
29	27	60	.9310345	.9714829	.8581666
29	27	65	.9310345	.9738643	.8517966
29	27	70	.9310345	.9763076	.8446466
29	27	75	.9310345	.9788412	.8364448
29	27	80	.9310345	.9815096	.826735
29	27	85	.9310345	.9843848	.8146808
29	27	90	.9310345	.9876061	.7984395
30	27	55	.9	.9482416	.8299608
30	27	60	.9	.9484166	.8238026
30	27	65	.9	.9516992	.8170388
30	27	70	.9	.9551298	.8094851
30	27	75	.9	.958764	.8008573
30	27	80	.9	.9628923	.7907006
30	27	85	.9	.9670641	.7781668

E=+/- .15

.9<=P<.95 RANGE

N	Y	CL	PROP	UPPER	LOWER
30	27	90	.9	.9721836	.7614066
30	28	95	.9333333	.9701732	.8083161
30	28	60	.9333333	.9724369	.8627124
30	28	65	.9333333	.9747393	.8565293
30	28	70	.9333333	.9771016	.8495871
30	28	75	.9333333	.9795513	.8416212
30	28	80	.9333333	.982131	.8321873
30	28	85	.9333333	.9849101	.8204705
30	28	90	.9333333	.9880239	.804674

E=+/- .15

.85<=P<.9 RANGE

N	Y	CL	PROP	UPPER	LOWER
14	12	55	.8571429	.9359289	.7290636
14	12	60	.8571429	.9407111	.7185587
15	13	55	.8666667	.9402195	.7458276
15	13	60	.8666667	.9446909	.7358519
15	13	65	.8666667	.9492509	.7249243
16	14	55	.875	.9439714	.7606453
16	14	60	.875	.9481699	.751152
16	14	65	.875	.9524501	.7407431
16	14	70	.875	.9568505	.7291402
17	15	55	.8823529	.9472799	.773836
17	15	60	.8823529	.9512369	.7647831
17	15	65	.8823529	.9552698	.7548491
17	15	70	.8823529	.9594148	.7437656
18	16	55	.8888889	.9502195	.7856529
18	16	60	.8888889	.9539611	.7770033
18	16	65	.8888889	.9577738	.7675051
18	16	70	.8888889	.9616914	.7568998
18	16	75	.8888889	.9657609	.7447997
19	17	55	.8947368	.9528483	.7962993
19	17	60	.8947368	.9563969	.7880201
19	17	65	.8947368	.960012	.7789228
19	17	70	.8947368	.9637259	.7687585
19	17	75	.8947368	.9675829	.7571508
20	17	55	.85	.9175778	.7499486
20	17	60	.85	.9222905	.7413648
20	17	65	.85	.9271718	.7319763
20	17	70	.85	.932282	.7215381
20	17	75	.85	.9377066	.7096836
23	20	55	.8695652	.9284269	.7808628
23	20	60	.8695652	.9325419	.7731778
23	20	65	.8695652	.9368012	.7647581
23	20	70	.8695652	.941257	.7553803
23	20	75	.8695652	.9459833	.7447061
23	20	80	.8695652	.9510982	.7321863
24	21	55	.875	.9314348	.7895401
24	21	60	.875	.9353829	.782116
24	21	65	.875	.9394688	.7739788
24	21	70	.875	.943742	.764911
24	21	75	.875	.9482738	.7545833
24	21	80	.875	.9531774	.742462
24	21	85	.875	.9586401	.7275597
25	22	55	.88	.9342002	.7975578
25	22	60	.88	.9379941	.7903784
25	22	65	.88	.9419202	.782506
25	22	70	.88	.9460251	.7737294
25	22	75	.88	.9503779	.7637278
25	22	80	.88	.9550866	.7519818
25	22	85	.88	.9603314	.7375301
26	23	55	.8846154	.936751	.8049882
26	23	60	.8846154	.9404027	.7980385
26	23	65	.8846154	.9441804	.7904149
26	23	70	.8846154	.9481302	.7819122

.85<=P<.9 RANGE		E=+/- .15			
N	Y	CL	PROP	UPPER	LOWER
26	23	75	.8846154	.9523176	.7722175
26	23	80	.8846154	.9568461	.7608259
26	23	85	.8846154	.9618896	.7468005
27	23	55	.8518519	.9094182	.7707471
27	23	60	.8518519	.9137516	.7638656
27	23	65	.8518519	.9182737	.755713
27	23	70	.8518519	.9230479	.746984
27	23	75	.8518519	.9281682	.7370693
27	23	80	.8518519	.9337828	.7254641
27	23	85	.8518519	.940142	.7112395
27	24	55	.8888889	.9391114	.8118935
27	24	60	.8888889	.9426309	.8051596
27	24	65	.8888889	.9462716	.7977701
27	24	70	.8888889	.9500774	.7895255
27	24	75	.8888889	.9541111	.7801205
27	24	80	.8888889	.9584729	.7690636
27	24	85	.8888889	.9633301	.7554414
28	24	55	.8571429	.9126915	.7785545
28	24	60	.8571429	.9168751	.7715806
28	24	65	.8571429	.9212406	.7639523
28	24	70	.8571429	.9258484	.7554692
28	24	75	.8571429	.9307893	.745829
28	24	80	.8571429	.9362082	.7345391
28	24	85	.8571429	.9423393	.7206915
28	25	55	.8928571	.9413018	.8183272
28	25	60	.8928571	.9446984	.8117966
28	25	65	.8928571	.9482115	.8046277
28	25	70	.8928571	.9518834	.7966265
28	25	75	.8928571	.9557745	.7874951
28	25	80	.8928571	.9599817	.7767546
28	25	85	.8928571	.9646652	.7635145
28	25	90	.8928571	.9701521	.745834
29	25	55	.862069	.915736	.7858486
29	25	60	.862069	.9197802	.7790714
29	25	65	.862069	.9239994	.7716555
29	25	70	.862069	.928452	.7634057
29	25	75	.862069	.9332258	.7540262
29	25	80	.862069	.9384581	.743036
29	25	85	.862069	.9443811	.7295477
29	26	55	.8965517	.9433401	.8243361
29	26	60	.8965517	.9466221	.817997
29	26	65	.8965517	.950016	.8110365
29	26	70	.8965517	.953563	.8032652
29	26	75	.8965517	.9573215	.7943925
29	26	80	.8965517	.9613847	.7839516
29	26	85	.8965517	.96569071	.7710738
29	26	90	.8965517	.9712038	.753865
30	26	55	.8666667	.9185756	.7926786
30	26	60	.8666667	.9224892	.7860877
30	26	65	.8666667	.9265717	.7788733
30	26	70	.8666667	.9308791	.7708449
30	26	75	.8666667	.9354962	.7617131
30	26	80	.8666667	.9405562	.7510084
30	26	85	.8666667	.9462832	.7378627
30	26	90	.8666667	.9531443	.7203864

E=+/- .15

.8<=P<.85 RANGE

M	Y	CL	PROP	UPPER	LOWER
13	11	55	.8461538	.9309743	.709946
13	11	60	.8461538	.9361136	.698859
15	12	55	.8	.8897032	.6732453
15	12	60	.8	.8959191	.6626541
15	12	65	.8	.9023698	.6511206
16	13	55	.8125	.8966926	.6921116
16	13	60	.8125	.9025358	.6819837
16	13	65	.8125	.9085969	.6709425
17	14	55	.8235294	.9028479	.7089297
17	14	60	.8235294	.9083608	.6992318
17	14	65	.8235294	.9140766	.688649
17	14	70	.8235294	.9200664	.6769132
18	15	55	.8333333	.9083104	.7240138
18	15	60	.8333333	.913528	.714715
18	15	65	.8333333	.9189359	.7045591
18	15	70	.8333333	.9246008	.6932857
19	16	55	.8421053	.9131908	.7376179
19	16	60	.8421053	.9181431	.7286898
19	16	65	.8421053	.9232743	.7189311
19	16	70	.8421053	.9286478	.7080895
19	16	75	.8421053	.9343532	.695788
20	16	55	.8	.8771772	.6957303
20	16	60	.8	.8829532	.6867001
20	16	65	.8	.8889919	.6768628
20	16	70	.8	.8953798	.6659733
20	16	75	.8	.9022432	.6536653
24	20	55	.8333333	.8979382	.7436438
24	20	60	.8333333	.9027913	.7357632
24	20	65	.8333333	.9078591	.7271574
24	20	70	.8333333	.9132135	.7176052
24	20	75	.8333333	.9189593	.7067741
24	20	80	.8333333	.9252652	.6941208
25	20	55	.8	.8685708	.7101634
25	20	60	.8	.8739654	.7021872
25	20	65	.8	.8796315	.6934986
25	20	70	.8	.8856571	.6838803
25	20	75	.8	.8921726	.673006
25	20	80	.8	.8993821	.6603411
25	21	55	.84	.9020754	.7533611
25	21	60	.84	.9067418	.7457273
25	21	65	.84	.911614	.7373868
25	21	70	.84	.9167597	.7281244
25	21	75	.84	.922283	.7176152
25	21	80	.84	.9283384	.7053295
25	21	85	.84	.9352019	.6902936
26	21	55	.8076923	.8737135	.7207024
26	21	60	.8076923	.8789115	.7129565
26	21	65	.8076923	.8843699	.7045145
26	21	70	.8076923	.8901728	.6951641
26	21	75	.8076923	.8964462	.6845858
26	21	80	.8076923	.9033851	.6722572
26	22	55	.8461538	.9058901	.7623708

.8<=P<.85 RANGE		E=+/- .15			
N	Y	CL	PROP	UPPER	LOWER
26	22	60	.8461538	.9103834	.7549696
26	22	65	.8461538	.9150742	.74688
26	22	70	.8461538	.9200273	.7378916
26	22	75	.8461538	.9253406	.7276875
26	22	80	.8461538	.9311681	.7157506
26	22	85	.8461538	.9377696	.7011303
27	22	55	.8148148	.8784682	.7305049
27	22	60	.8148148	.8834835	.7229772
27	22	65	.8148148	.8887488	.7147698
27	22	70	.8148148	.894345	.7056746
27	22	75	.8148148	.9003931	.695379
27	22	80	.8148148	.9070812	.6833719
27	22	85	.8148148	.9147421	.6687167
28	23	55	.8214286	.8828779	.7306441
28	23	60	.8214286	.8877228	.7323245
28	23	65	.8214286	.8928077	.7243403
28	23	70	.8214286	.8982114	.7154883
28	23	75	.8214286	.9040499	.7054624
28	23	80	.8214286	.9105046	.6937628
28	23	85	.8214286	.9178958	.6794721
29	24	55	.8275862	.8869784	.7481861
29	24	60	.8275862	.8916639	.7410638
29	24	65	.8275862	.8965809	.733292
29	24	70	.8275862	.9018045	.7246716
29	24	75	.8275862	.9074449	.7149033
29	24	80	.8275862	.9136844	.7034976
29	24	85	.8275862	.9208244	.6895565
30	24	55	.8	.8622189	.720322
30	24	60	.8	.8672913	.7131145
30	24	65	.8	.8726362	.7052647
30	24	70	.8	.8783406	.6965761
30	24	75	.8	.8845344	.686753
30	24	80	.8	.8914226	.6753111
30	24	85	.8	.899368	.6613648
30	25	55	.8333333	.8908008	.7561868
30	25	60	.8333333	.8953373	.7492526
30	25	65	.8333333	.9000968	.7416826
30	25	70	.8333333	.9051522	.7332833
30	25	75	.8333333	.9106124	.7237608
30	25	80	.8333333	.9166484	.7126365
30	25	85	.8333333	.9235506	.6990303

E=+/- .15

.7<=P<.8 RANGE

M	Y	CL	PROP	UPPER	LOWER
14	11	55	.7857143	.881698	.6519363
14	11	60	.7857143	.8883369	.6408465
15	11	55	.7333333	.8352586	.6032898
15	11	60	.7333333	.8428288	.5923745
16	12	55	.75	.84579	.6259726
16	12	60	.75	.852918	.615481
16	12	65	.75	.8603842	.6040882
17	12	55	.7058824	.804996	.5852405
17	12	60	.7058824	.8127161	.5749365
17	12	65	.7058824	.8208515	.5637823
17	13	55	.7647059	.8550533	.6462255
17	13	60	.7647059	.8617878	.6361332
17	13	65	.7647059	.8688379	.6251598
18	13	55	.7222222	.8161238	.6063913
18	13	60	.7222222	.823451	.5964264
18	13	65	.7222222	.8311676	.5856264
18	13	70	.7222222	.8393975	.5737436
18	14	55	.7777778	.8632647	.6644131
18	14	60	.7777778	.8696468	.6546935
18	14	65	.7777778	.8763241	.644123
18	14	70	.7777778	.8833934	.632444
19	14	55	.7368421	.8260467	.6255088
19	14	60	.7368421	.8330183	.6158704
19	14	65	.7368421	.8403571	.6054131
19	14	70	.7368421	.8481792	.5938946
19	15	55	.7894737	.8705945	.6808333
19	15	60	.7894737	.8766583	.671469
19	15	65	.7894737	.8830007	.6612756
19	15	70	.7894737	.889712	.6500021
20	14	55	.7	.7913468	.5911195
20	14	60	.7	.7987206	.5816235
20	14	65	.7	.806516	.5713426
20	14	70	.7	.8148656	.5600426
20	15	55	.75	.8349614	.6428696
20	15	60	.75	.8416	.6335436
20	15	65	.75	.8485952	.6234158
20	15	70	.75	.8560475	.6122494
26	20	55	.7692308	.8405684	.6797946
26	20	60	.7692308	.8463675	.6717924
26	20	65	.7692308	.8524835	.6630866
26	20	70	.7692308	.8590178	.6534731
26	20	75	.7692308	.8661177	.6426333
26	20	80	.7692308	.8740298	.6300317
27	20	55	.7407407	.8139907	.6520733
27	20	60	.7407407	.8200931	.6440847
27	20	65	.7407407	.8265474	.6354122
27	20	70	.7407407	.8334733	.6258515
27	20	75	.7407407	.8410258	.61509
27	20	80	.7407407	.8494823	.6026091
27	21	55	.7777778	.8465958	.690984
27	21	60	.7777778	.8521947	.6831952
27	21	65	.7777778	.8580979	.6747168

R=+/- .15

.7<=P<.8 RANGE

N	Y	CL	PROP	UPPER	LOWER
27	21	70	.7777778	.8044032	.6653494
27	21	75	.7777778	.8712552	.6547808
27	21	80	.7777778	.8788816	.642484
28	20	55	.7142857	.788817	.6266308
28	20	60	.7142857	.7951477	.6186911
28	20	65	.7142857	.8018604	.6100841
28	20	70	.7142857	.8090828	.600609
28	20	75	.7142857	.8169853	.5899601
28	20	80	.7142857	.8258662	.5776388
28	21	55	.75	.8207916	.6637771
28	21	60	.75	.8266944	.6559846
28	21	65	.75	.8329383	.6475208
28	21	70	.75	.8396309	.638185
28	21	75	.75	.8469294	.6276702
28	21	80	.75	.8550988	.615465
28	21	85	.75	.8645818	.6006614
28	22	55	.7857143	.8521834	.7014211
28	22	60	.7857143	.8575952	.693833
28	22	65	.7857143	.8632999	.6855755
28	22	70	.7857143	.8693913	.6764441
28	22	75	.7857143	.8760091	.666131
28	22	80	.7857143	.8833723	.6541332
28	22	85	.7857143	.8918712	.6395308
29	21	55	.7241379	.7962918	.6387388
29	21	60	.7241379	.8024256	.630979
29	21	65	.7241379	.8089281	.6225626
29	21	70	.7241379	.8159221	.6132921
29	21	75	.7241379	.8235718	.6028666
29	21	80	.7241379	.8321649	.5907886
29	21	85	.7241379	.8421868	.5761676
29	22	55	.7586207	.8271116	.6747231
29	22	60	.7586207	.8328273	.6671195
29	22	65	.7586207	.8388714	.6588566
29	22	70	.7586207	.8453482	.6497378
29	22	75	.7586207	.8524121	.6394617
29	22	80	.7586207	.8603094	.6275243
29	22	85	.7586207	.8694771	.6130339
29	23	55	.7931034	.8873779	.7111793
29	23	60	.7931034	.8826146	.7037858
29	23	65	.7931034	.8681335	.6957365
29	23	70	.7931034	.8740251	.6868313
29	23	75	.7931034	.8804239	.6767682
29	23	80	.7931034	.8875415	.6650537
29	23	85	.7931034	.8957542	.6507852
30	21	55	.7	.7730511	.6156018
30	21	60	.7	.7793596	.607898
30	21	65	.7	.7860618	.5995524
30	21	70	.7	.7932854	.5903711
30	21	75	.7	.8012082	.5800595
30	21	80	.7	.8101351	.568137
30	21	85	.7	.8205852	.5537198
30	22	55	.7333333	.8032539	.6500907
30	22	60	.7333333	.809203	.6425052
30	22	65	.7333333	.8155078	.6342736

E=+/- .15

.7<=P<.8 RANGE		CL	PROP	UPPER	LOWER
N	Y				
30	22	70	.7333333	.8222868	.625202
30	22	75	.7333333	.8297022	.6149943
30	22	80	.7333333	.8380226	.6031596
30	22	85	.7333333	.8477264	.5888212
30	23	55	.7666667	.8330003	.6849796
30	23	60	.7666667	.8385401	.6775601
30	23	65	.7666667	.8443967	.6694906
30	23	70	.7666667	.8506709	.6605811
30	23	75	.7666667	.8575118	.6505358
30	23	80	.7666667	.8651574	.6388558
30	23	85	.7666667	.8740296	.6246721

E=+/- .175

P = 1.00 RANGE

N	Y	CL	PROP	UPPER	LOWER
5	5	60	1		.8325532
6	6	65	1		.8394819
7	7	70	1		.8419825
8	8	75	1		.8408964
9	9	80	1		.836251
10	10	85	1		.8271973
11	11	85	1		.8415874
12	12	90	1		.8254042
13	13	90	1		.8376777
14	14	90	1		.8483429
15	15	90	1		.8576959
16	16	95	1		.8292503
17	17	95	1		.8384339
18	18	95	1		.8466824
19	19	95	1		.8541314
20	20	95	1		.8608917
21	21	95	1		.8670541
22	22	95	1		.8726946
23	23	95	1		.8778766
24	24	95	1		.8826538
25	25	95	1		.8870719
26	26	95	1		.8911697
27	27	95	1		.8949808
28	28	95	1		.8985343
29	29	95	1		.9018554
30	30	95	1		.9049661

E=+/- .175

.95<=P<1.00 RANGE

N	Y	CL	PROP	UPPER	LOWER
20	19	55	.95	.9873364	.8645598
20	19	60	.95	.9889040	.8575677
20	19	65	.95	.9904275	.8498204
20	19	70	.95	.9919071	.8410817
20	19	75	.95	.9933456	.8310133
20	19	80	.95	.9947459	.8190396
20	19	85	.95	.9961095	.804109
20	19	90	.95	.9974387	.7838939
21	20	55	.952381	.9879358	.8707267
21	20	60	.952381	.9894304	.8640275
21	20	65	.952381	.9908812	.8566017
21	20	70	.952381	.9922909	.8482217
21	20	75	.952381	.9936616	.8385613
21	20	80	.952381	.9949954	.8270656
21	20	85	.952381	.9962945	.8127197
21	20	90	.952381	.9975604	.7932746
22	21	55	.9545455	.988481	.8763571
22	21	60	.9545455	.9899084	.8699274
22	21	65	.9545455	.991294	.8627978
22	21	70	.9545455	.99264	.8547486
22	21	75	.9545455	.9939488	.8454651
22	21	80	.9545455	.9952222	.8344114
22	21	85	.9545455	.9964628	.8206076
22	21	90	.9545455	.9976712	.8018779
23	22	55	.9565217	.9889791	.8815178
23	22	60	.9565217	.990345	.8753373
23	22	65	.9565217	.9916709	.8684812
23	22	70	.9565217	.9929589	.8607382
23	22	75	.9565217	.9942111	.8518036
23	22	80	.9565217	.9954296	.8411598
23	22	85	.9565217	.9966161	.8279594
23	22	90	.9565217	.9977723	.8097961
24	23	55	.9583333	.9894358	.8862652
24	23	60	.9583333	.9907456	.8803154
24	23	65	.9583333	.9920166	.8737131
24	23	70	.9583333	.9932512	.866254
24	23	75	.9583333	.9944516	.8576434
24	23	80	.9583333	.9956196	.8473807
24	23	85	.9583333	.9967569	.8345432
24	23	90	.9583333	.9978651	.8171076
24	23	95	.9583333	.9989456	.7887998
25	24	55	.96	.9898562	.8906474
25	24	60	.96	.9911114	.8849117
25	24	65	.96	.9923346	.8785451
25	24	70	.96	.9935204	.87135
25	24	75	.96	.994673	.8630412
25	24	80	.96	.9957945	.8531336
25	24	85	.96	.9968864	.8407333
25	24	90	.96	.9979504	.8238793
25	24	95	.96	.9989878	.7964847
26	25	55	.9615385	.9902445	.8947046
26	25	60	.9615385	.9914544	.8891681

E=+/- .175

.95<=P<1.00 RANGE

N	Y	CL	PROP	UPPER	LOWER
26	25	65	.9615385	.9926284	.8830212
26	25	70	.9615385	.9937688	.8760724
26	25	75	.9615385	.9948773	.8680449
26	25	80	.9615385	.9959559	.8584692
26	25	85	.9615385	.9970059	.8464779
26	25	90	.9615385	.9980291	.8301688
26	25	95	.9615385	.9990268	.8036322
27	26	55	.962963	.9906041	.8984716
27	26	60	.962963	.9917696	.8931212
27	26	65	.962963	.9929005	.8871794
27	26	70	.962963	.9939989	.8804606
27	26	75	.962963	.9950666	.8726965
27	26	80	.962963	.9961054	.8634313
27	26	85	.962963	.9971167	.8518233
27	26	90	.962963	.9981021	.8360256
27	26	95	.962963	.9990628	.8102965
28	27	55	.9642857	.9909382	.9019785
28	27	60	.9642857	.9920623	.8968022
28	27	65	.9642857	.9931531	.8910524
28	27	70	.9642857	.9942126	.8845491
28	27	75	.9642857	.9952424	.8770316
28	27	80	.9642857	.9962442	.8680878
28	27	85	.9642857	.9972195	.8568096
28	27	90	.9642857	.9981698	.8414929
28	27	95	.9642857	.9990962	.8165248
29	28	55	.9655172	.9912493	.9052514
29	28	60	.9655172	.9923349	.9002383
29	28	65	.9655172	.9933885	.8946684
29	28	70	.9655172	.9944118	.8883674
29	28	75	.9655172	.9954061	.8810815
29	28	80	.9655172	.9963734	.8723813
29	28	85	.9655172	.9973153	.8614717
29	28	90	.9655172	.9982328	.8466608
29	28	95	.9655172	.9991274	.8223583
30	29	55	.9666667	.9915397	.9083129
30	29	60	.9666667	.9925895	.9034531
30	29	65	.9666667	.9936082	.8980523
30	29	70	.9666667	.9945973	.8919414
30	29	75	.9666667	.9955589	.8848735
30	29	80	.9666667	.9964942	.8764309
30	29	85	.9666667	.9974046	.8658404
30	29	90	.9666667	.9982917	.8514039
30	29	95	.9666667	.9991564	.8278335

.9<=P<.95 RANGE				E=+/- .175		
N	Y	CL	PROP	UPPER	LOWER	
10	9	55	.9	.9748331	.7413034	
10	9	60	.9	.9779329	.7290119	
12	11	55	.9166667	.9789832	.7810837	
12	11	60	.9166667	.9815767	.7703831	
12	11	65	.9166667	.9840968	.7585924	
12	11	70	.9166667	.9865481	.7453951	
13	12	55	.9230769	.980584	.7967273	
13	12	60	.9230769	.9829817	.7866843	
13	12	65	.9230769	.9853111	.7756054	
13	12	70	.9230769	.9875764	.7631897	
13	12	75	.9230769	.9897809	.7489589	
14	13	55	.9285714	.9819584	.8102898	
14	13	60	.9285714	.9841876	.8008313	
14	13	65	.9285714	.9863532	.7903867	
14	13	70	.9285714	.9884586	.7786645	
14	13	75	.9285714	.9905074	.7652206	
15	14	55	.9333333	.9831509	.8221597	
15	14	60	.9333333	.9852339	.8132233	
15	14	65	.9333333	.9872571	.8033468	
15	14	70	.9333333	.9892239	.7922516	
15	14	75	.9333333	.9911374	.7795126	
15	14	80	.9333333	.9930006	.7644316	
16	15	55	.9375	.9841956	.8326345	
16	15	60	.9375	.9861504	.8241669	
16	15	65	.9375	.9880488	.8148017	
16	15	70	.9375	.9898894	.8042722	
16	15	75	.9375	.9916889	.7921709	
16	15	80	.9375	.9934366	.7778285	
17	16	55	.9411765	.9851184	.841946	
17	16	60	.9411765	.9869598	.8339016	
17	16	65	.9411765	.9887478	.8249987	
17	16	70	.9411765	.9904856	.8149814	
17	16	75	.9411765	.992176	.8034594	
17	16	80	.9411765	.9938215	.7897895	
17	16	85	.9411765	.9954246	.772793	
18	17	55	.9444444	.9859392	.8502776	
18	17	60	.9444444	.9876798	.8426168	
18	17	65	.9444444	.9893696	.8341372	
18	17	70	.9444444	.9910118	.8245825	
18	17	75	.9444444	.992609	.8135881	
18	17	80	.9444444	.9941638	.8005331	
18	17	85	.9444444	.9956782	.7842832	
19	18	55	.9473684	.9866744	.8577758	
19	18	60	.9473684	.9883244	.8504644	
19	18	65	.9473684	.9899262	.8423672	
19	18	70	.9473684	.9914829	.8332383	
19	18	75	.9473684	.9929967	.8227268	
19	18	80	.9473684	.9944701	.810235	
19	18	85	.9473684	.9959052	.7946716	
19	18	90	.9473684	.997304	.7736258	
20	18	55	.9	.9552136	.8059403	
20	18	60	.9	.9585879	.7980025	

E=+/- .175

.9<=P<.95 RANGE

N	Y	CL	PROP	UPPER	LOWER
20	18	65	.9	.9620249	.789275
20	18	70	.9	.9655552	.7795179
20	18	75	.9	.9692208	.7683666
20	18	80	.9	.9730858	.7552348
20	18	85	.9	.9772555	.739032
22	20	55	.9090909	.9592967	.8227261
22	20	60	.9090909	.9623695	.8153948
22	20	65	.9090909	.9654983	.8073266
22	20	70	.9090909	.9687108	.7982972
22	20	75	.9090909	.9720456	.7879631
22	20	80	.9090909	.9755602	.7757762
22	20	85	.9090909	.9793507	.760712
22	20	90	.9090909	.9836021	.7405411
23	21	55	.9130435	.9610712	.8300768
23	21	60	.9130435	.9640125	.8230164
23	21	65	.9130435	.9670071	.8152428
23	21	70	.9130435	.9700814	.8065356
23	21	75	.9130435	.9732719	.7965721
23	21	80	.9130435	.9766345	.7848108
23	21	85	.9130435	.9802598	.7702611
23	21	90	.9130435	.9843253	.7507597
24	22	55	.9166667	.9626974	.8368431
24	22	60	.9166667	.9655182	.8300347
24	22	65	.9166667	.9683894	.8225354
24	22	70	.9166667	.9713368	.814132
24	22	75	.9166667	.9743952	.8045113
24	22	80	.9166667	.9776181	.793148
24	22	85	.9166667	.9810924	.7790805
24	22	90	.9166667	.9849879	.760199
25	23	55	.92	.9641931	.8430919
25	23	60	.92	.9669028	.8365184
25	23	65	.92	.9696605	.8292753
25	23	70	.92	.9724909	.8211557
25	23	75	.92	.9754279	.8118556
25	23	80	.92	.9785222	.8008651
25	23	85	.92	.9818576	.7872503
25	23	90	.92	.9855964	.7689601
26	24	55	.9230769	.9655736	.8488804
26	24	60	.9230769	.9681805	.8425263
26	24	65	.9230769	.9708334	.8355228
26	24	70	.9230769	.9735561	.8276689
26	24	75	.9230769	.9763804	.8186694
26	24	80	.9230769	.979356	.8080288
26	24	85	.9230769	.982563	.7948395
26	24	90	.9230769	.9861576	.7771063
26	24	95	.9230769	.9905448	.7486972
27	25	55	.9259259	.9668516	.8542574
27	25	60	.9259259	.9693631	.8481088
27	25	65	.9259259	.9719188	.8413299
27	25	70	.9259259	.9745416	.8337251
27	25	75	.9259259	.9772619	.825008
27	25	80	.9259259	.9801277	.8146963
27	25	85	.9259259	.9832156	.8019077
27	25	90	.9259259	.9866767	.7847001
27	25	95	.9259259	.9909002	.7571018

E=+/- .175

.9<=P<.95 RANGE

M	Y	CL	PROP	UPPER	LOWER
28	26	55	.9285714	.968038	.8592653
28	26	60	.9285714	.9704611	.8533097
28	26	65	.9285714	.9729265	.8467415
28	26	70	.9285714	.9754563	.839371
28	26	75	.9285714	.9780801	.8309191
28	26	80	.9285714	.9808436	.8209171
28	26	85	.9285714	.9838212	.8085063
28	26	90	.9285714	.9871581	.7917953
28	26	95	.9285714	.9912296	.7649655
29	27	55	.9310345	.9691424	.8639408
29	27	60	.9310345	.9714829	.8581666
29	27	65	.9310345	.9738643	.8517966
29	27	70	.9310345	.9763076	.8446466
29	27	75	.9310345	.9788412	.8364448
29	27	80	.9310345	.9815096	.826735
29	27	85	.9310345	.9843848	.8146808
29	27	90	.9310345	.9876061	.7984395
29	27	95	.9310345	.9915362	.7723383
30	27	55	.9	.9452416	.8299608
30	27	60	.9	.9494166	.8238026
30	27	65	.9	.9516992	.8170388
30	27	70	.9	.9551298	.8094851
30	27	75	.9	.958764	.8008573
30	27	80	.9	.9626923	.7907006
30	27	85	.9	.9670641	.7781668
30	27	90	.9	.9721836	.7614066
30	27	95	.9	.9788829	.7347116
30	28	55	.9333333	.9701732	.8683161
30	28	60	.9333333	.9724365	.8627124
30	28	65	.9333333	.9747393	.8565293
30	28	70	.9333333	.9771016	.8498871
30	28	75	.9333333	.9795513	.8416212
30	28	80	.9333333	.982131	.8321873
30	28	85	.9333333	.9849101	.8204705
30	28	90	.9333333	.9880239	.804674
30	28	95	.9333333	.9918216	.7792648

.85<=P<.9 RANGE E=+/- .175

M	Y	CL	PROP	UPPER	LOWER
9	8	55	.88888889	.9720762	.7154899
14	12	55	.8571429	.9359289	.7290636
14	12	60	.8571429	.9407111	.7185587
14	12	65	.8571429	.9455898	.7070637
14	12	70	.8571429	.9506086	.6942785
15	13	55	.8666667	.9402195	.7458276
15	13	60	.8666667	.9446909	.7358519
15	13	65	.8666667	.9492509	.7249243
15	13	70	.8666667	.9539401	.7127558
15	13	75	.8666667	.9588157	.6989191
16	14	55	.875	.9439714	.7606453
16	14	60	.875	.9481699	.751152
16	14	65	.875	.9524501	.7407431
16	14	70	.875	.9568505	.7291402
16	14	75	.875	.9614242	.7159299
16	14	80	.875	.9662512	.700436
17	15	55	.8823529	.9472799	.773836
17	15	60	.8823529	.9512369	.7647831
17	15	65	.8823529	.9552698	.7548491
17	15	70	.8823529	.9594148	.7437656
17	15	75	.8823529	.9637218	.7311328
17	15	80	.8823529	.9682661	.7162083
18	16	55	.8888889	.9502195	.7856529
18	16	60	.8888889	.9539611	.7770033
18	16	65	.8888889	.9577738	.7675051
18	16	70	.8888889	.9616914	.7568998
18	16	75	.8888889	.9657609	.7447997
18	16	80	.8888889	.9700538	.7305758
19	17	55	.8947368	.9528483	.7962993
19	17	60	.8947368	.9563969	.7880201
19	17	65	.8947368	.960012	.7789228
19	17	70	.8947368	.9637259	.7687585
19	17	75	.8947368	.9675829	.7571508
19	17	80	.8947368	.9716508	.7434932
19	17	85	.8947368	.9760399	.7266595
20	17	55	.85	.9175778	.7499486
20	17	60	.85	.9222905	.7413648
20	17	65	.85	.9271718	.7319763
20	17	70	.85	.932282	.7215381
20	17	75	.85	.9377066	.7096836
20	17	80	.85	.9435822	.6958132
20	17	85	.85	.9501355	.678827
23	20	55	.8695652	.9284269	.7808628
23	20	60	.8695652	.9325419	.7731778
23	20	65	.8695652	.9368012	.7647581
23	20	70	.8695652	.941257	.7553803
23	20	75	.8695652	.9459833	.7447061
23	20	80	.8695652	.9510982	.7321863
23	20	85	.8695652	.9567983	.7168073
23	20	90	.8695652	.9634837	.6963644
24	21	55	.875	.9314348	.7895401
24	21	60	.875	.9353829	.782116

E=+/- .175

.85<=P<.9 RANGE

N	Y	CL	PROP	UPPER	LOWER
24	21	65	.875	.9394688	.7739788
24	21	70	.875	.943742	.764911
24	21	75	.875	.9482738	.7545833
24	21	80	.875	.9531774	.742462
24	21	85	.875	.9586401	.7275597
24	21	90	.875	.9650458	.7077292
25	22	55	.88	.9342002	.7975578
25	22	60	.88	.9379941	.7903784
25	22	65	.88	.9419202	.782506
25	22	70	.88	.9460251	.7737294
25	22	75	.88	.9503779	.7637278
25	22	80	.88	.9550866	.7519818
25	22	85	.88	.9603314	.7375301
25	22	90	.88	.9664794	.7182803
26	23	55	.8846154	.936751	.8049882
26	23	60	.8846154	.9404027	.7980385
26	23	65	.8846154	.9441804	.7904149
26	23	70	.8846154	.9481302	.7819122
26	23	75	.8846154	.9523176	.7722175
26	23	80	.8846154	.9568461	.7608259
26	23	85	.8846154	.9618896	.7468005
26	23	90	.8846154	.9678	.7281011
27	23	55	.8518519	.9094182	.7707471
27	23	60	.8518519	.9137516	.7635656
27	23	65	.8518519	.9182737	.755713
27	23	70	.8518519	.9230479	.746984
27	23	75	.8518519	.9281682	.7370693
27	23	80	.8518519	.9337828	.7254641
27	23	85	.8518519	.940142	.7112395
27	23	90	.8518519	.9477658	.6923748
27	24	55	.8888889	.9391114	.8118935
27	24	60	.8888889	.9426309	.8051596
27	24	65	.8888889	.9462716	.7977701
27	24	70	.8888889	.9500774	.7895255
27	24	75	.8888889	.9541111	.7801205
27	24	80	.8888889	.9584729	.7690636
27	24	85	.8888889	.9633301	.7554414
27	24	90	.8888889	.9690208	.7372646
28	24	55	.8571429	.9126915	.7785545
28	24	60	.8571429	.9168751	.7715806
28	24	65	.8571429	.9212406	.7639523
28	24	70	.8571429	.9258484	.7554692
28	24	75	.8571429	.9307893	.746829
28	24	80	.8571429	.9362062	.7345391
28	24	85	.8571429	.9423393	.7206915
28	24	90	.8571429	.9496909	.7023107
28	25	55	.8928571	.9413018	.8183272
28	25	60	.8928571	.9446984	.8117966
28	25	65	.8928571	.9482115	.8046277
28	25	70	.8928571	.9518834	.7966265
28	25	75	.8928571	.9557745	.7874951
28	25	80	.8928571	.9598817	.7767546
28	25	85	.8928571	.9646652	.7635145
28	25	90	.8928571	.9701521	.745834
29	25	55	.862069	.915736	.7858486

E=+/- .175

.85<=P<.9 RANGE		CL	PROP	UPPER	LOWER
N	Y				
29	25	60	.862069	.9197802	.7790714
29	25	65	.862069	.9239994	.7716555
29	25	70	.862069	.928452	.7634057
29	25	75	.862069	.9332258	.7540262
29	25	80	.862069	.9384581	.743036
29	25	85	.862069	.9443811	.7295477
29	25	90	.862069	.9514788	.7116294
29	25	95	.8965517	.9433401	.8243361
29	26	60	.8965517	.9466221	.817997
29	26	65	.8965517	.950016	.8110365
29	26	70	.8965517	.953563	.8032652
29	26	75	.8965517	.9573215	.7943925
29	26	80	.8965517	.9613847	.7839516
29	26	85	.8965517	.9659071	.7710738
29	26	90	.8965517	.9712038	.753865
29	26	95	.8965517	.9781367	.7264848
30	26	55	.8666667	.9185756	.7926786
30	26	60	.8666667	.9224892	.7860877
30	26	65	.8666667	.9265717	.7786733
30	26	70	.8666667	.9308791	.7708449
30	26	75	.8666667	.9354962	.7617131
30	26	80	.8666667	.9405562	.7510084
30	26	85	.8666667	.9462832	.7378627
30	26	90	.8666667	.9531443	.7203864
30	26	95	.8666667	.9624464	.692795

E=+/- .175

.8<=P<.85 RANGE

N	Y	CL	PROP	UPPER	LOWER
10	8	55	.8	.9101174	.632267
13	11	55	.8461538	.9309743	.709946
13	11	60	.8461538	.9361136	.698859
13	11	65	.8461538	.9413589	.6867422
13	11	70	.8461538	.9467569	.6732843
15	12	55	.8	.8897032	.6732453
15	12	60	.8	.8959191	.6628541
15	12	65	.8	.9023695	.6511206
15	12	70	.8	.909135	.638361
16	13	55	.8125	.8966926	.6921116
16	13	60	.8125	.9025358	.6819837
16	13	65	.8125	.9085969	.6709425
16	13	70	.8125	.9149511	.6587117
16	13	75	.8125	.9217056	.6448813
17	14	55	.8235294	.9028479	.7089297
17	14	60	.8235294	.9083608	.6992318
17	14	65	.8235294	.9140766	.688649
17	14	70	.8235294	.9200664	.6769132
17	14	75	.8235294	.9264309	.6636255
18	15	55	.8333333	.9083104	.7240138
18	15	60	.8333333	.913528	.714715
18	15	65	.8333333	.9189359	.7045591
18	15	70	.8333333	.9246008	.6932857
18	15	75	.8333333	.9306177	.6805071
18	15	80	.8333333	.9371395	.6655875
19	16	55	.8421053	.9131908	.7376179
19	16	60	.8421053	.9181431	.7286899
19	16	65	.8421053	.9232743	.7189311
19	16	70	.8421053	.9286478	.7080895
19	16	75	.8421053	.9343532	.695788
19	16	80	.8421053	.9405351	.6814092
20	16	55	.8	.8771772	.6957303
20	16	60	.8	.8829532	.6867001
20	16	65	.8	.8889919	.6766628
20	16	70	.8	.8953798	.6659733
20	16	75	.8	.9022432	.6536653
20	16	80	.8	.9097863	.6393381
24	20	55	.8333333	.8979382	.7436438
24	20	60	.8333333	.9027913	.7357632
24	20	65	.8333333	.9078591	.7271574
24	20	70	.8333333	.9132135	.7176062
24	20	75	.8333333	.9189593	.7067741
24	20	80	.8333333	.9252652	.6941208
24	20	85	.8333333	.9324126	.6786486
25	20	55	.8	.8685708	.7101634
25	20	60	.8	.8739654	.7021872
25	20	65	.8	.8796315	.6934986
25	20	70	.8	.8856571	.6838803
25	20	75	.8	.8921726	.673006
25	20	80	.8	.8993821	.6603411
25	20	85	.8	.9076461	.6449099
25	21	55	.84	.9020754	.7533611

K=+/- .175

.8<=P<.85 RANGE

N	Y	CL	PROP	UPPER	LOWER
25	21	60	.84	.9067418	.7467273
25	21	65	.84	.911614	.7373868
25	21	70	.84	.9167597	.7281244
25	21	75	.84	.922283	.7176152
25	21	80	.84	.9283384	.7053295
25	21	85	.84	.9352019	.6902936
25	21	90	.84	.9434364	.6703925
26	21	55	.8076923	.8737135	.7207024
26	21	60	.8076923	.8789115	.7129865
26	21	65	.8076923	.8843699	.7045145
26	21	70	.8076923	.8901728	.6951641
26	21	75	.8076923	.8964462	.6845858
26	21	80	.8076923	.9033881	.6722572
26	21	85	.8076923	.9113358	.657222
26	21	90	.8076923	.9210131	.6374054
26	22	55	.8461538	.9058901	.7623708
26	22	60	.8461538	.9103834	.7549696
26	22	65	.8461538	.9150742	.74688
26	22	70	.8461538	.9200273	.7378916
26	22	75	.8461538	.9253406	.7276875
26	22	80	.8461538	.9311681	.7157506
26	22	85	.8461538	.9377696	.7011303
26	22	90	.8461538	.9456871	.6817591
27	22	55	.8148148	.8784682	.7305045
27	22	60	.8148148	.8834835	.7229772
27	22	65	.8148148	.8887488	.7147698
27	22	70	.8148148	.894345	.7056746
27	22	75	.8148148	.9003931	.695379
27	22	80	.8148148	.9070812	.6833719
27	22	85	.8148148	.9147421	.6687167
27	22	90	.8148148	.9240627	.6493806
28	23	55	.8214286	.8828779	.7396441
28	23	60	.8214286	.8877228	.7323245
28	23	65	.8214286	.8928077	.7243403
28	23	70	.8214286	.8982114	.7154883
28	23	75	.8214286	.9040499	.7054624
28	23	80	.8214286	.9105046	.6937628
28	23	85	.8214286	.9178958	.6794721
28	23	90	.8214286	.9268852	.6605984
29	24	55	.8275862	.8869784	.7481861
29	24	60	.8275862	.8916639	.7410638
29	24	65	.8275862	.8965809	.733292
29	24	70	.8275862	.9018045	.7246716
29	24	75	.8275862	.9074449	.7149033
29	24	80	.8275862	.9136844	.7034976
29	24	85	.8275862	.9208244	.6896565
29	24	90	.8275862	.929505	.6711278
30	24	55	.8	.8622189	.720322
30	24	60	.8	.8672913	.7131145
30	24	65	.8	.8726362	.7052647
30	24	70	.8	.8783406	.6965761
30	24	75	.8	.8845344	.686753
30	24	80	.8	.8914226	.6753111
30	24	85	.8	.899368	.6613648
30	24	90	.8	.9091254	.6429911

E=+/- .175

.8<=P<.85 RANGE		CL	PROP	UPPER	LOWER
N	Y				
30	25	55	.8333333	.8908008	.7561868
30	25	60	.8333333	.8953373	.7492526
30	25	65	.8333333	.9000968	.7416826
30	25	70	.8333333	.9051922	.7332833
30	25	75	.8333333	.9106124	.7237608
30	25	80	.8333333	.9166454	.7126365
30	25	85	.8333333	.9235506	.6990303
30	25	90	.8333333	.9319436	.6810294

E=+/- .175

.7<=P<.8 RANGE

N	Y	CL	PROP	UPPER	LOWER
10	7	55	.7	.8332522	.5297415
10	7	55	.7	.8332522	.5297415
14	11	55	.7857143	.881698	.6519363
14	11	60	.7857143	.8883369	.6408465
14	11	65	.7857143	.8952299	.6287861
14	11	70	.7857143	.9024606	.6154631
15	11	55	.7333333	.8352586	.6032898
15	11	60	.7333333	.8428288	.5923745
15	11	65	.7333333	.8507626	.580543
15	11	70	.7333333	.8591762	.5675256
16	12	55	.75	.84579	.6259726
16	12	60	.75	.852918	.615481
16	12	65	.75	.8603842	.6040882
16	12	70	.75	.8682968	.5915355
16	12	75	.75	.8768151	.5774205
17	12	55	.7058824	.804996	.5852405
17	12	60	.7058824	.8127161	.5749365
17	12	65	.7058824	.8208515	.5637823
17	12	70	.7058824	.8295333	.5515257
17	12	75	.7058824	.8389555	.5377833
17	13	55	.7647059	.8550533	.6462255
17	13	60	.7647059	.8617878	.6361332
17	13	65	.7647059	.8688379	.6251598
17	13	70	.7647059	.8763051	.6130541
17	13	75	.7647059	.8843394	.5994228
18	13	55	.7222222	.8161238	.6063913
18	13	60	.7222222	.823451	.5964264
18	13	65	.7222222	.8311676	.5856264
18	13	70	.7222222	.8393975	.5737436
18	13	75	.7222222	.8483234	.5604008
18	14	55	.7777778	.8632647	.6644131
18	14	60	.7777778	.8696468	.6546935
18	14	65	.7777778	.8763241	.644123
18	14	70	.7777778	.8833934	.632444
18	14	75	.7777778	.8909957	.6192775
18	14	80	.7777778	.8993591	.6039781
19	14	55	.7368421	.8260467	.6255088
19	14	60	.7368421	.8330183	.6158704
19	14	65	.7368421	.8403571	.6054131
19	14	70	.7368421	.8481792	.5938946
19	14	75	.7368421	.8566576	.5809447
19	14	80	.7368421	.8660644	.5689521
19	15	55	.7894737	.8705945	.6808333
19	15	60	.7894737	.8766583	.671469
19	15	65	.7894737	.8830007	.6612756
19	15	70	.7894737	.889712	.6500021
19	15	75	.7894737	.8969261	.637273
19	15	80	.7894737	.9046582	.6224731
20	14	55	.7	.7913468	.5911195
20	14	60	.7	.7987206	.5816235
20	14	65	.7	.806516	.5713426
20	14	70	.7	.8148656	.5600426

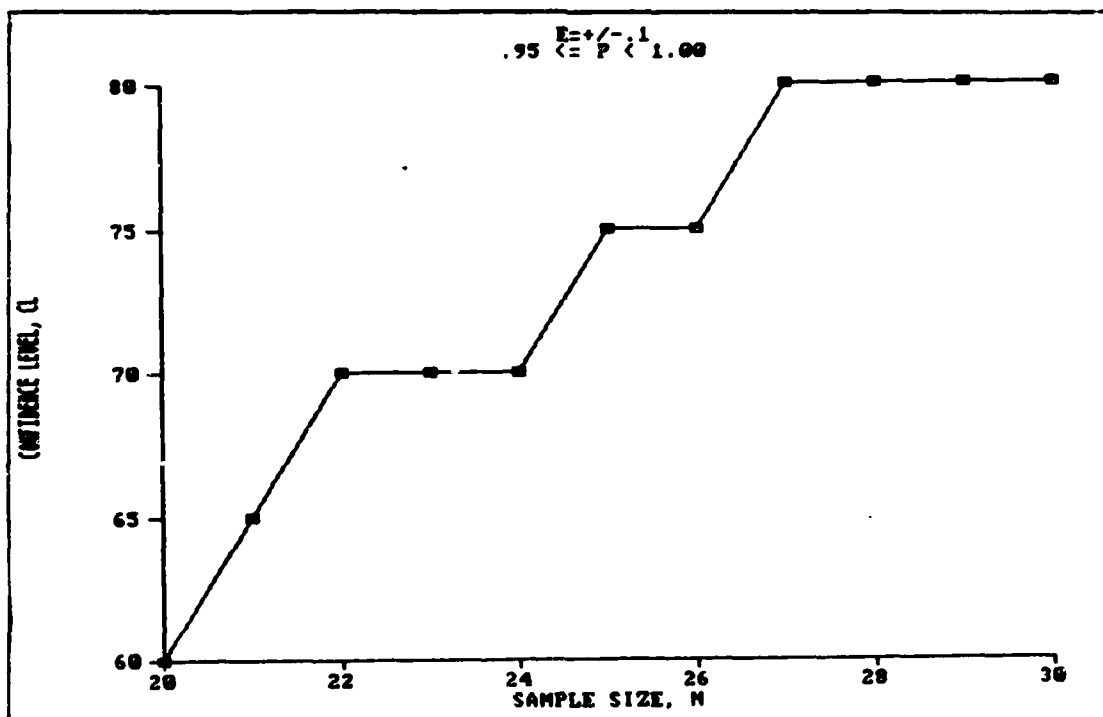
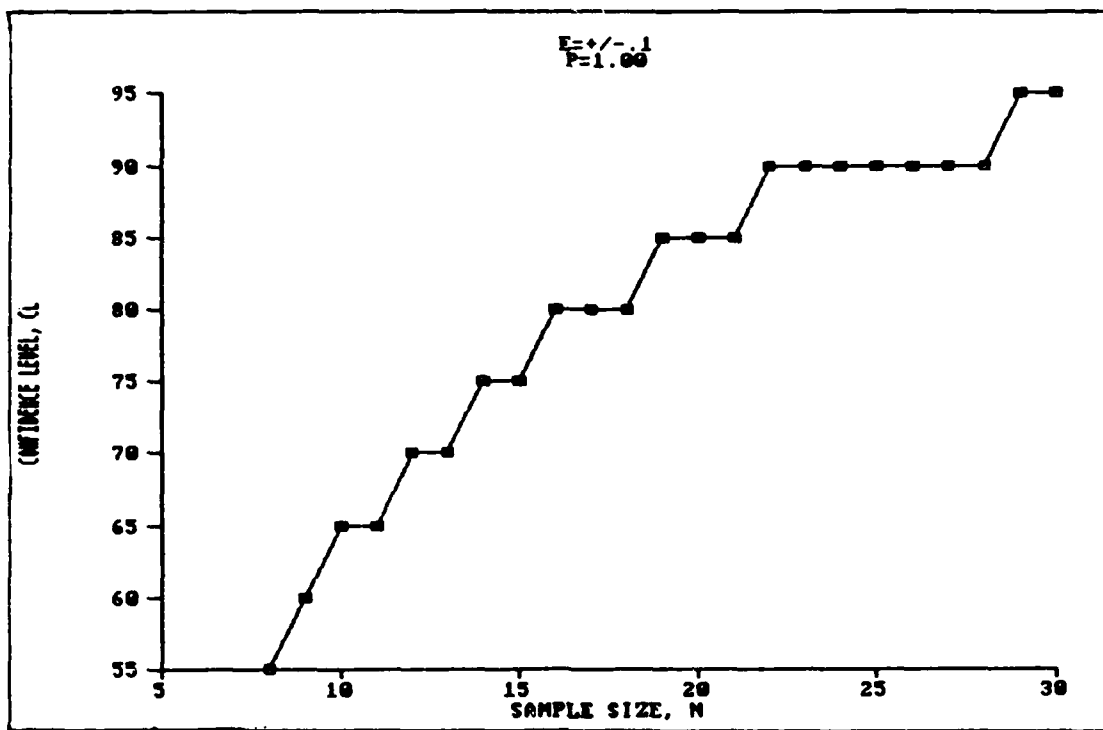
E=+/- .175

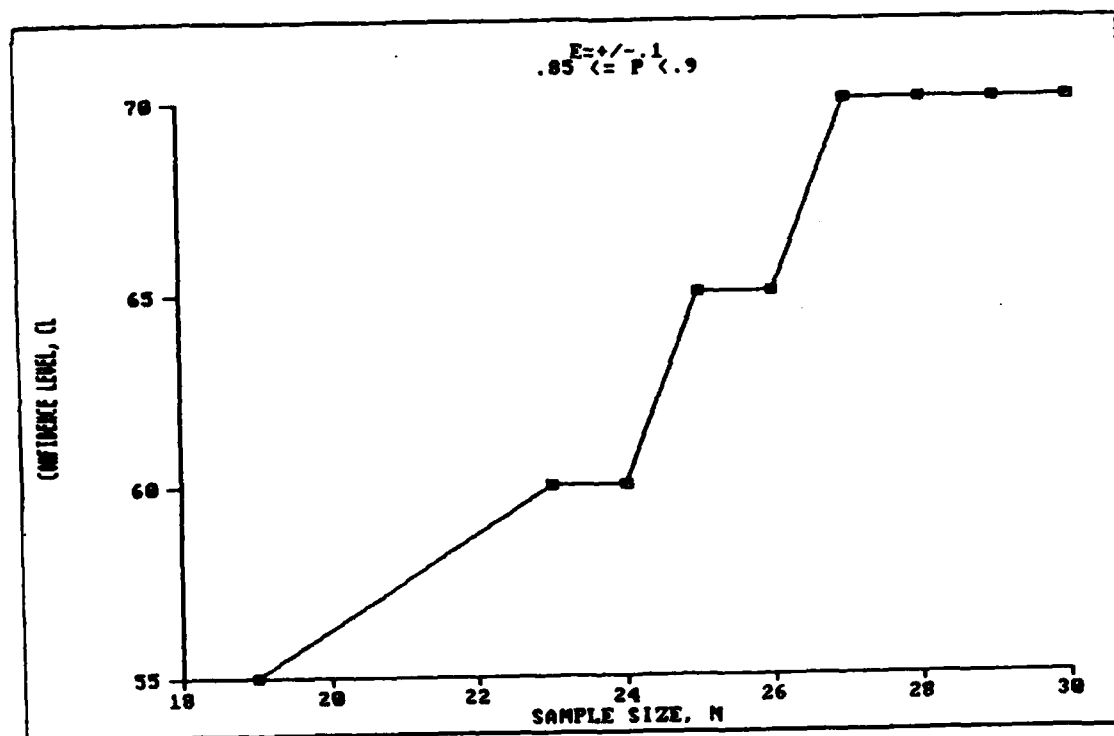
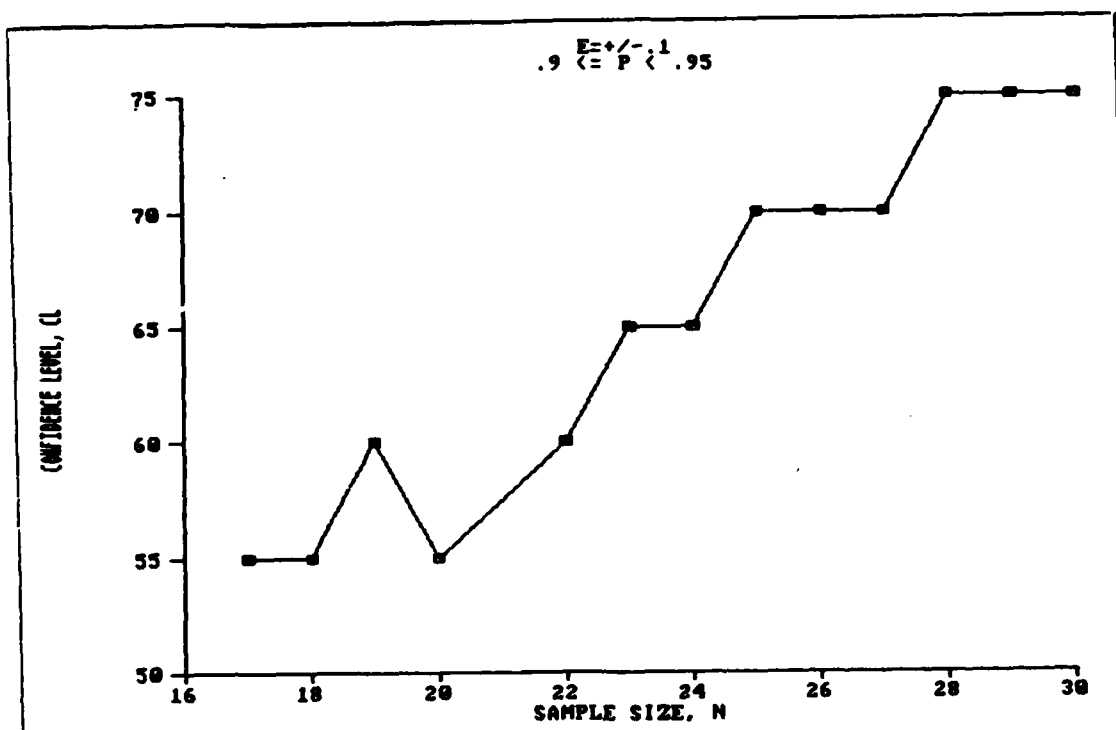
.7<=P<.8 RANGE

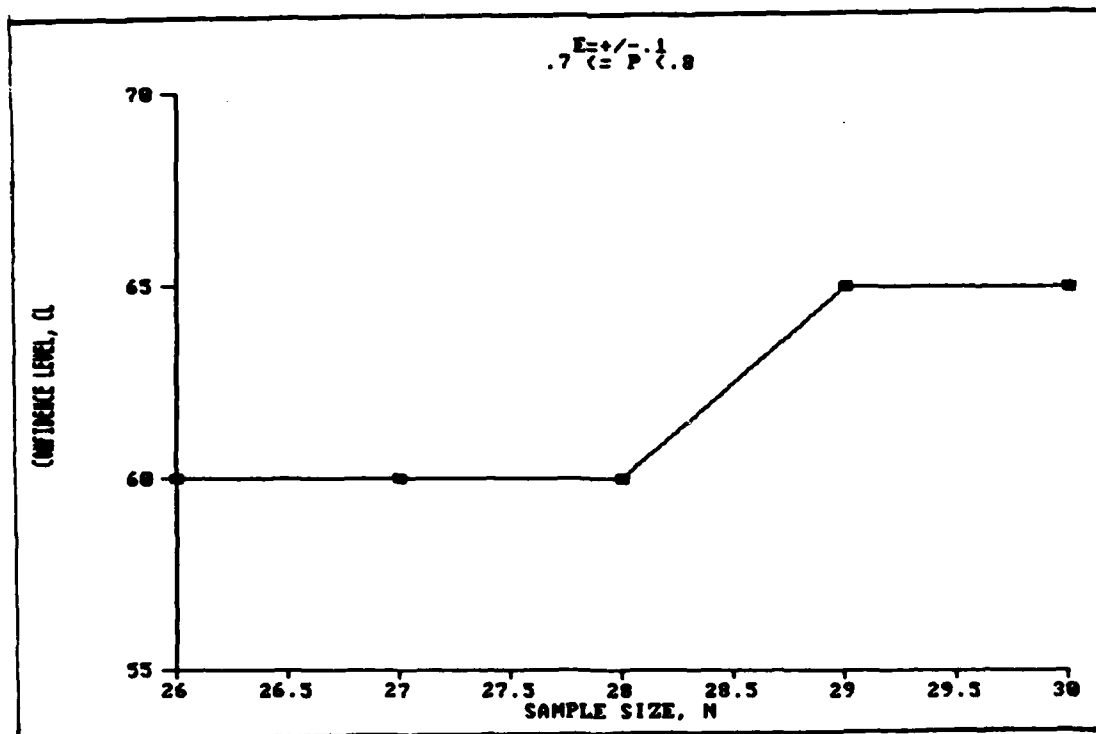
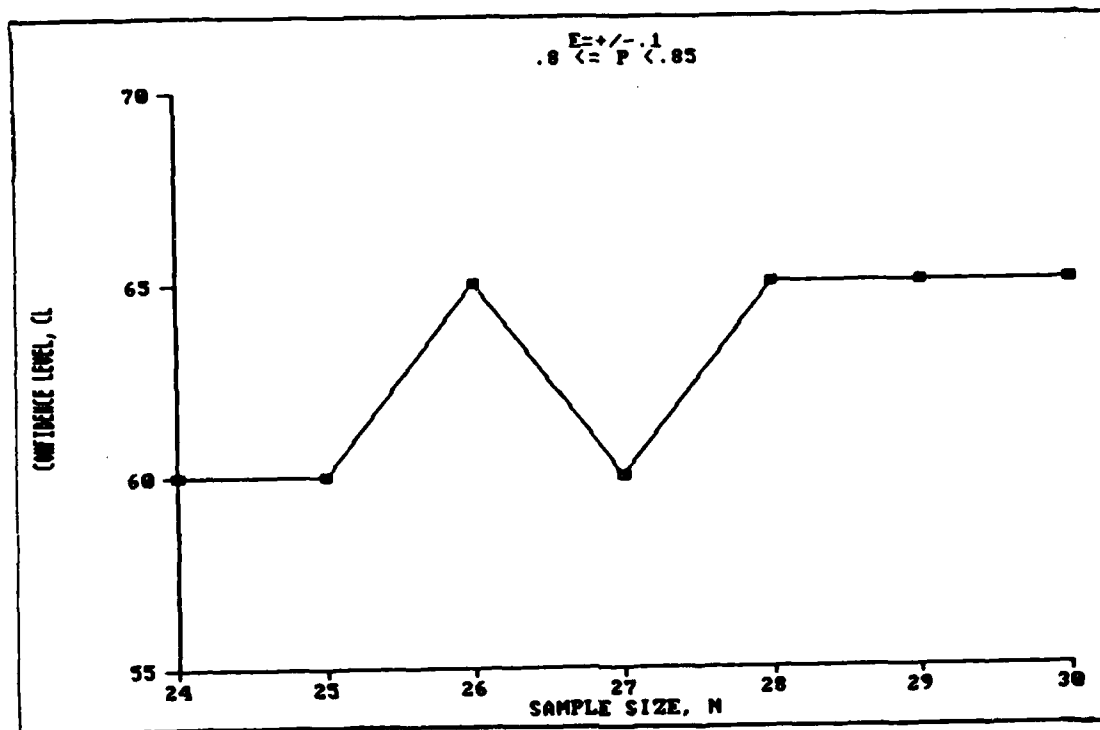
M	Y	CL	PROP	UPPER	LOWER
20	14	75	.7	.8239658	.547367
20	14	80	.7	.8341278	.5327361
20	15	55	.75	.8349514	.6428696
20	15	60	.75	.8416	.6335436
20	15	65	.75	.8468982	.6234158
20	15	70	.75	.8580475	.6122494
20	15	75	.75	.8641214	.5996815
20	15	80	.75	.8730738	.5851097
26	20	55	.7692308	.8405684	.6797946
26	20	60	.7692308	.8463675	.6717924
26	20	65	.7692308	.8524835	.6630866
26	20	70	.7692308	.8590178	.6534731
26	20	75	.7692308	.8661177	.6426333
26	20	80	.7692308	.8740298	.6300317
26	20	85	.7692308	.8831654	.6147261
26	20	90	.7692308	.8944029	.5946462
27	20	55	.7407407	.8139907	.6520733
27	20	60	.7407407	.8200931	.6440947
27	20	65	.7407407	.8265474	.6354122
27	20	70	.7407407	.8334733	.6258515
27	20	75	.7407407	.8410258	.61509
27	20	80	.7407407	.8494823	.6026091
27	20	85	.7407407	.8593035	.5874841
27	20	90	.7407407	.8714766	.567698
27	21	55	.7777778	.8465958	.690984
27	21	60	.7777778	.8521947	.6831952
27	21	65	.7777778	.8580979	.6747168
27	21	70	.7777778	.8644032	.6653494
27	21	75	.7777778	.8712552	.6547808
27	21	80	.7777778	.8788816	.642484
27	21	85	.7777778	.8876876	.627536
27	21	90	.7777778	.8985142	.6079018
28	20	55	.7142857	.788817	.6266308
28	20	60	.7142857	.7951477	.6186911
28	20	65	.7142857	.8018604	.6100841
28	20	70	.7142857	.8090828	.600609
28	20	75	.7142857	.8169853	.5899601
28	20	80	.7142857	.8258662	.5776388
28	20	85	.7142857	.8362273	.5627247
28	20	90	.7142857	.8491499	.5432691
28	21	55	.75	.8207916	.6637771
28	21	60	.75	.8266944	.6559846
28	21	65	.75	.8329383	.6475208
28	21	70	.75	.8396309	.638185
28	21	75	.75	.8469294	.6276702
28	21	80	.75	.8550988	.615469
28	21	85	.75	.8645618	.6006614
28	21	90	.75	.8763306	.5812724
28	22	55	.7857143	.8521834	.7014211
28	22	60	.7857143	.8575952	.693833
28	22	65	.7857143	.8632999	.6855755
28	22	70	.7857143	.8693913	.6764441
28	22	75	.7857143	.8760091	.666131
28	22	80	.7857143	.8833723	.6541332
28	22	85	.7857143	.8918712	.6395308

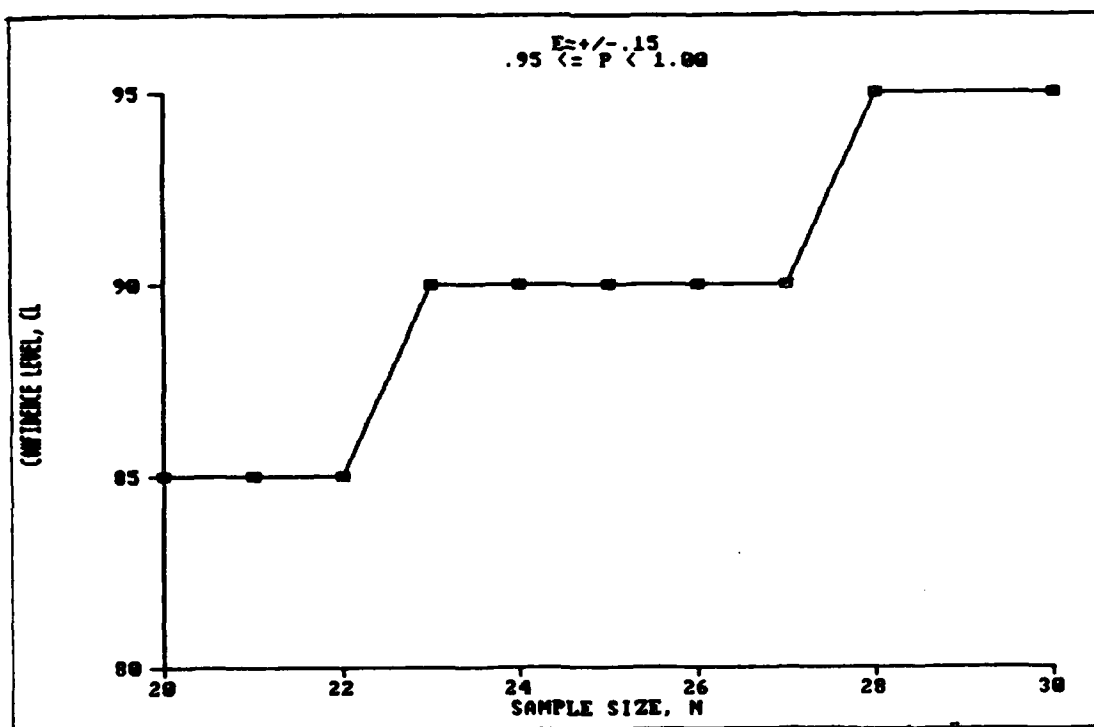
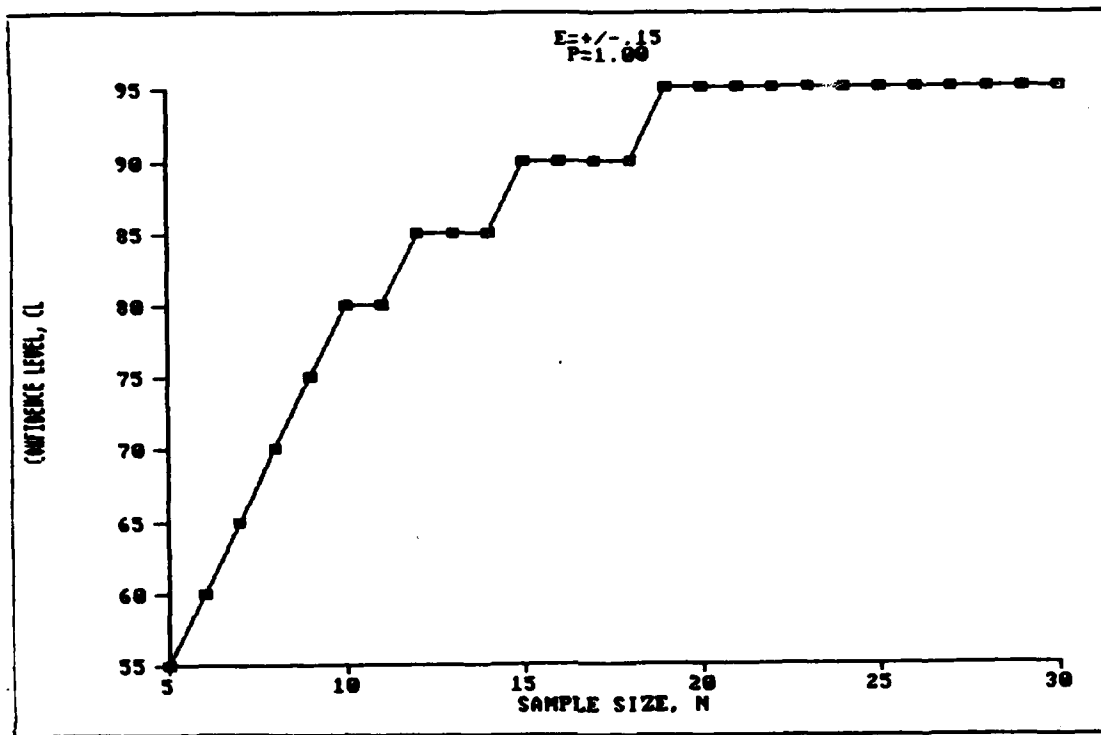
.7<=P<.8 RANGE		E=+/- .175				
N	Y	CL	PROP	UPPER	LOWER	
28	22	90	.7857143	.9023162	.6203301	
29	21	55	.7241379	.7962918	.6387388	
29	21	60	.7241379	.8024256	.6309979	
29	21	65	.7241379	.8089281	.6225626	
29	21	70	.7241379	.8159221	.6132921	
29	21	75	.7241379	.8235718	.6028666	
29	21	80	.7241379	.8321649	.5907886	
29	21	85	.7241379	.8421868	.5761676	
29	21	90	.7241379	.8546781	.5570641	
29	22	55	.7586207	.8271116	.6747231	
29	22	60	.7586207	.8328273	.6671195	
29	22	65	.7586207	.8388714	.6588566	
29	22	70	.7586207	.8453482	.6497378	
29	22	75	.7586207	.8524121	.6394617	
29	22	80	.7586207	.8603094	.6275243	
29	22	85	.7586207	.8694771	.6130339	
29	22	90	.7586207	.8808299	.5940341	
29	23	55	.7931034	.8573779	.7111793	
29	23	60	.7931034	.8626146	.7037858	
29	23	65	.7931034	.8681335	.6957365	
29	23	70	.7931034	.8740251	.6868313	
29	23	75	.7931034	.8804239	.6767682	
29	23	80	.7931034	.8875415	.6650537	
29	23	85	.7931034	.8957542	.6507852	
29	23	90	.7931034	.9058442	.6320046	
30	21	55	.7	.7730511	.6156018	
30	21	60	.7	.7793596	.6078998	
30	21	65	.7	.7860618	.5995524	
30	21	70	.7	.7932854	.5903711	
30	21	75	.7	.8012082	.5800595	
30	21	80	.7	.8101351	.568137	
30	21	85	.7	.8205852	.5537198	
30	21	90	.7	.8336738	.5349274	
30	22	55	.7333333	.8032539	.6500907	
30	22	60	.7333333	.809203	.6425052	
30	22	65	.7333333	.8155078	.6342736	
30	22	70	.7333333	.8222868	.625202	
30	22	75	.7333333	.8297022	.6149943	
30	22	80	.7333333	.8380226	.6031596	
30	22	85	.7333333	.8477264	.5888212	
30	22	90	.7333333	.8598142	.5700661	
30	23	55	.7666667	.8330003	.6849796	
30	23	60	.7666667	.8385401	.6775601	
30	23	65	.7666667	.8443967	.6694906	
30	23	70	.7666667	.8506709	.6605811	
30	23	75	.7666667	.8575118	.6505358	
30	23	80	.7666667	.8651574	.638858	
30	23	85	.7666667	.8740296	.6246721	
30	23	90	.7666667	.8850128	.6060526	

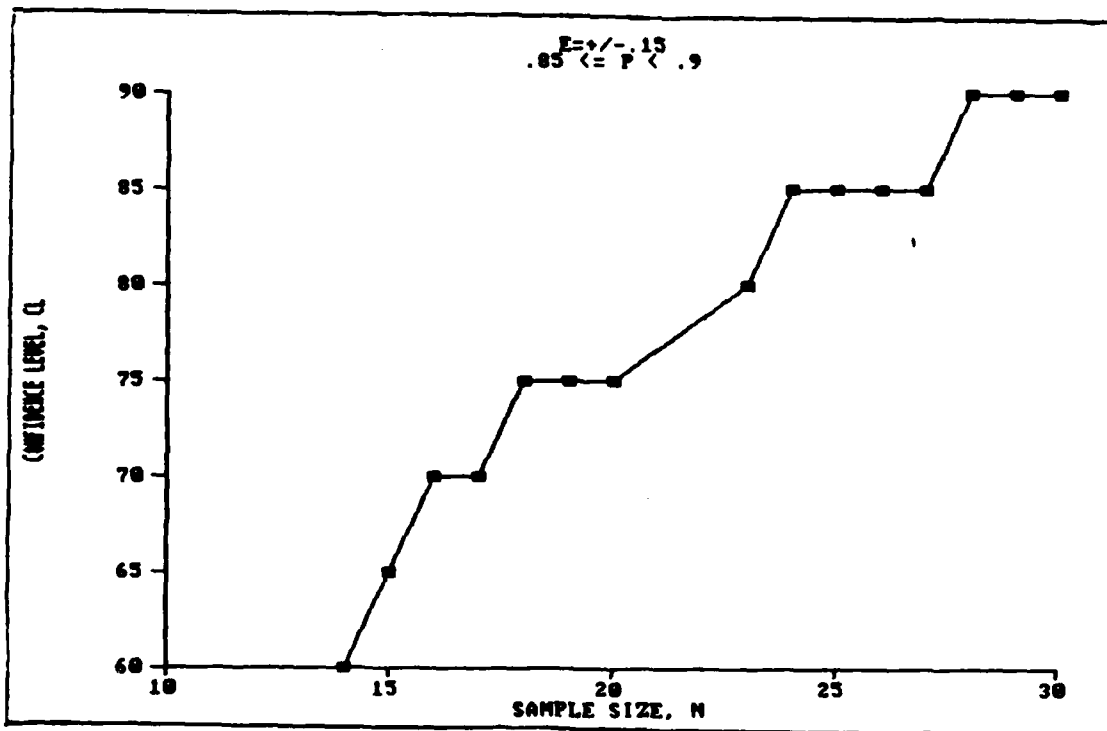
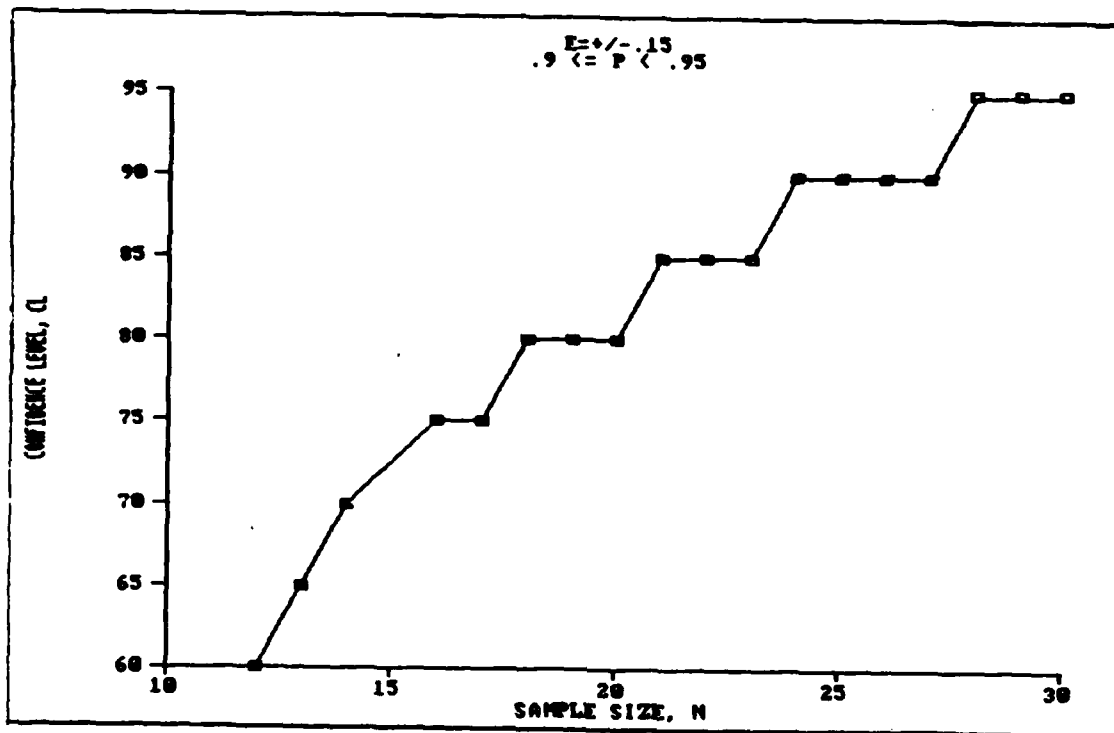
Appendix C: Proportion Graphs

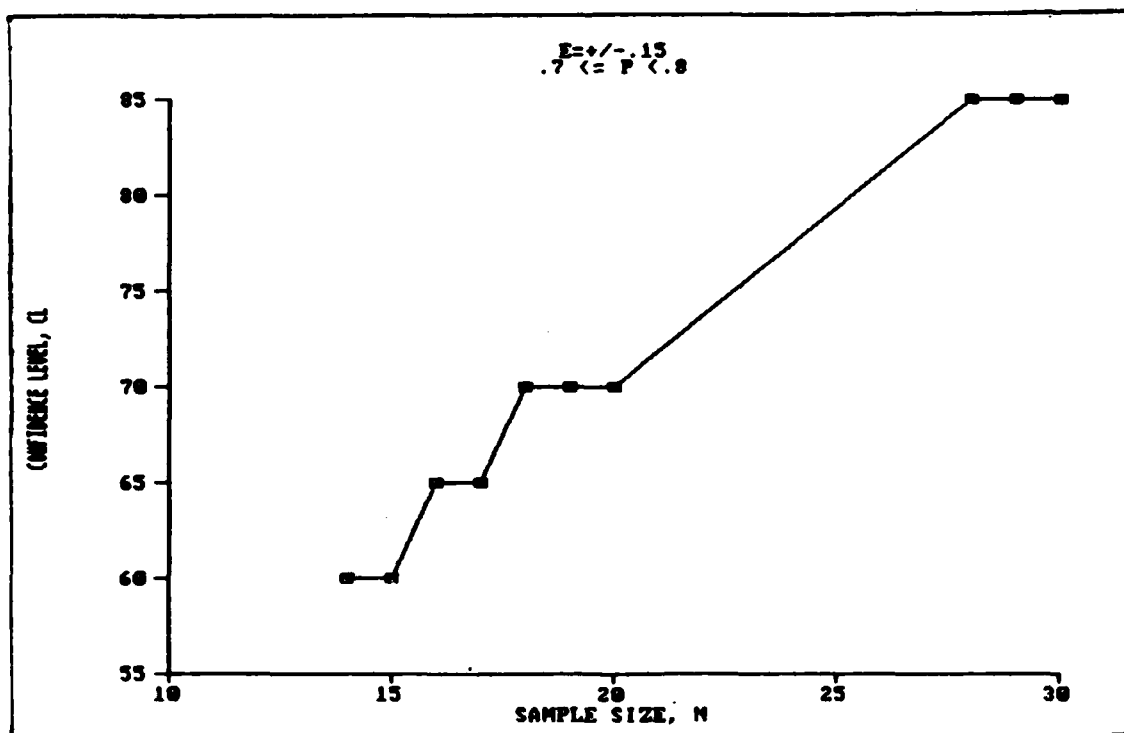
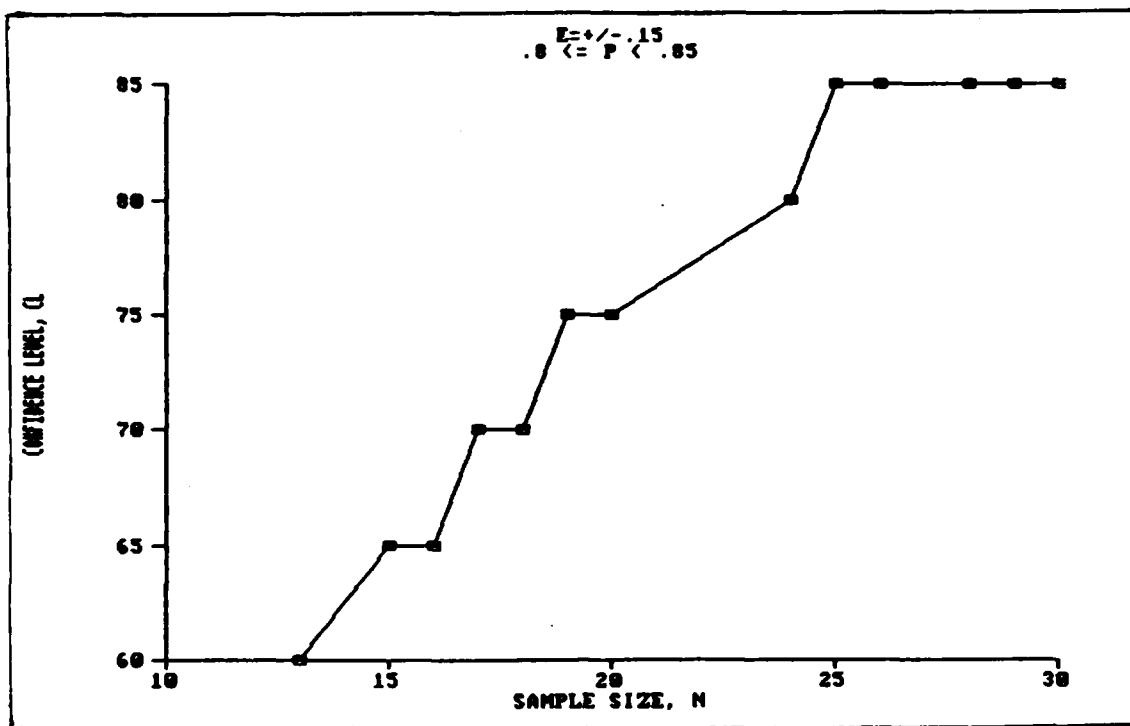


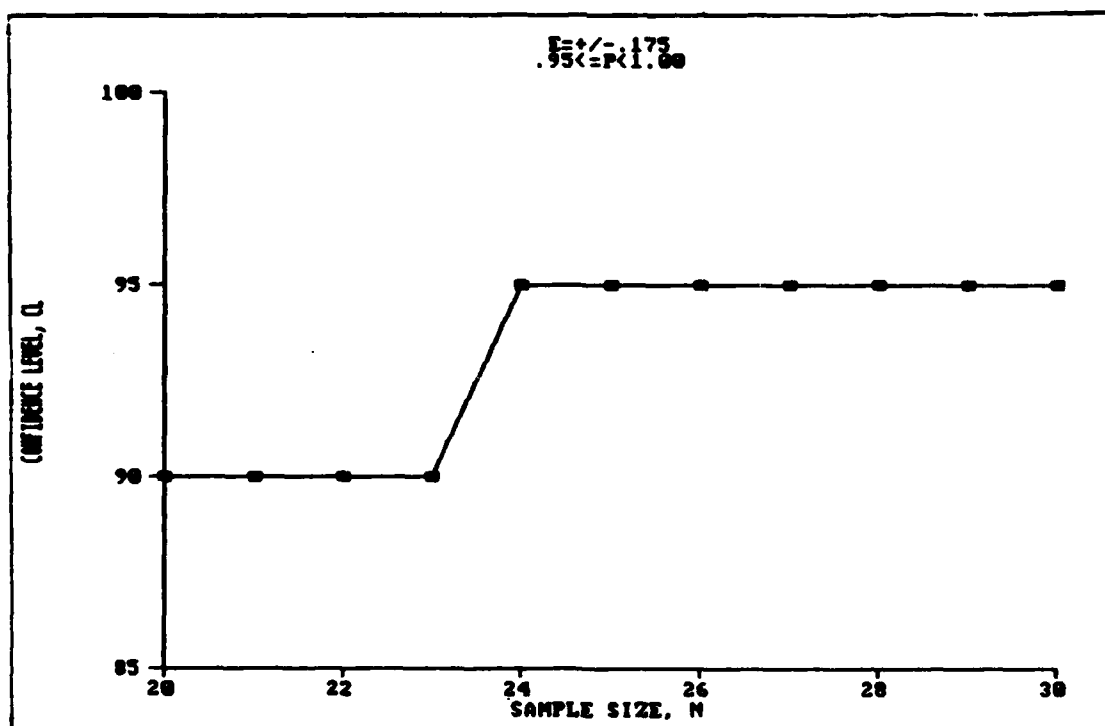
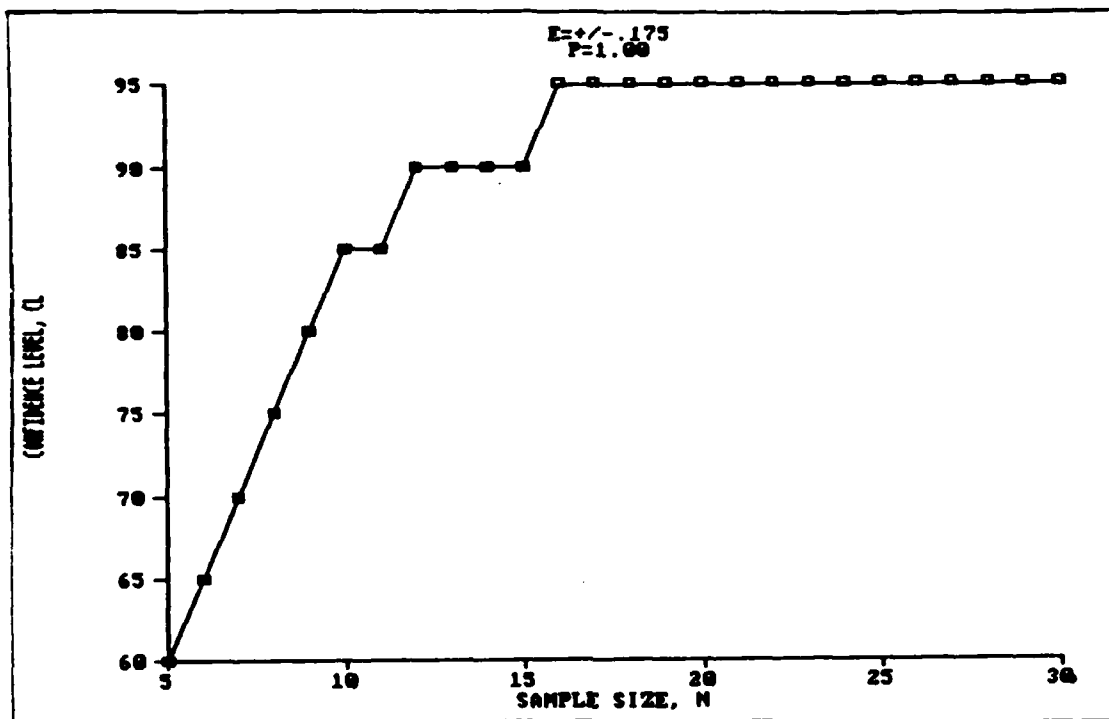


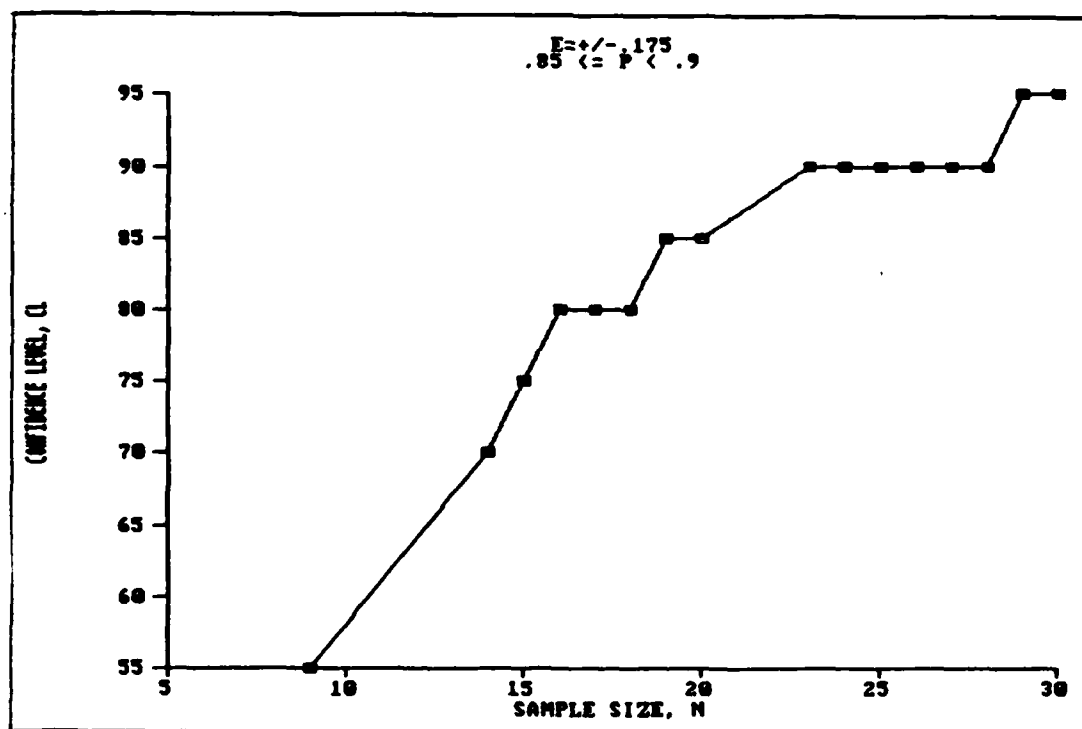
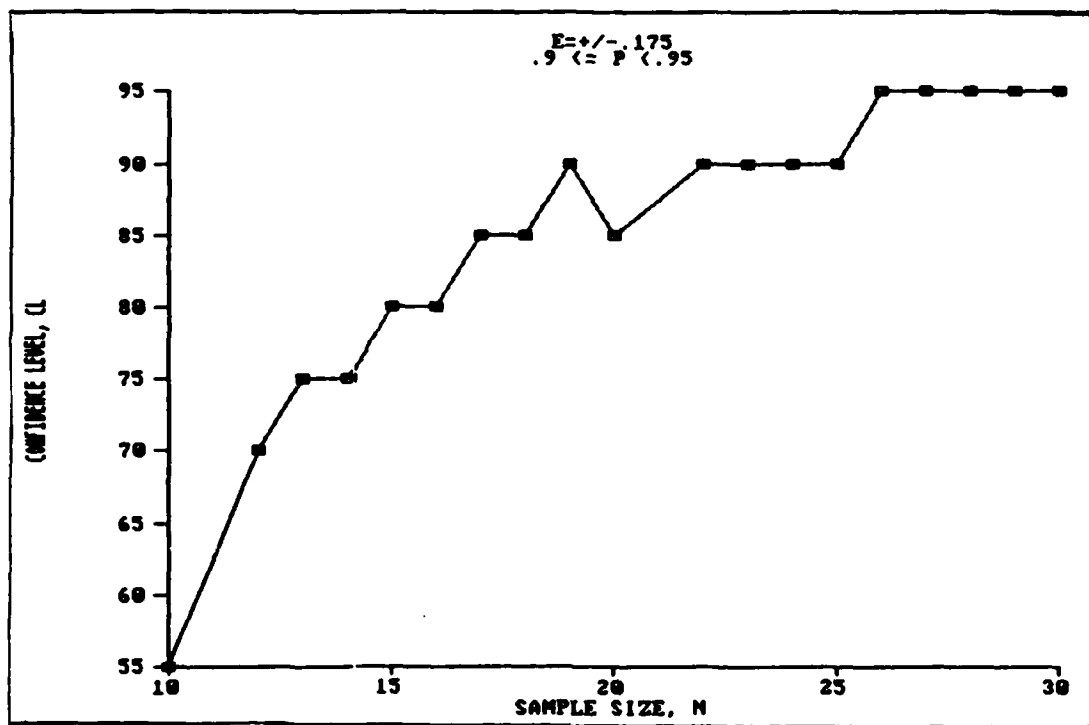


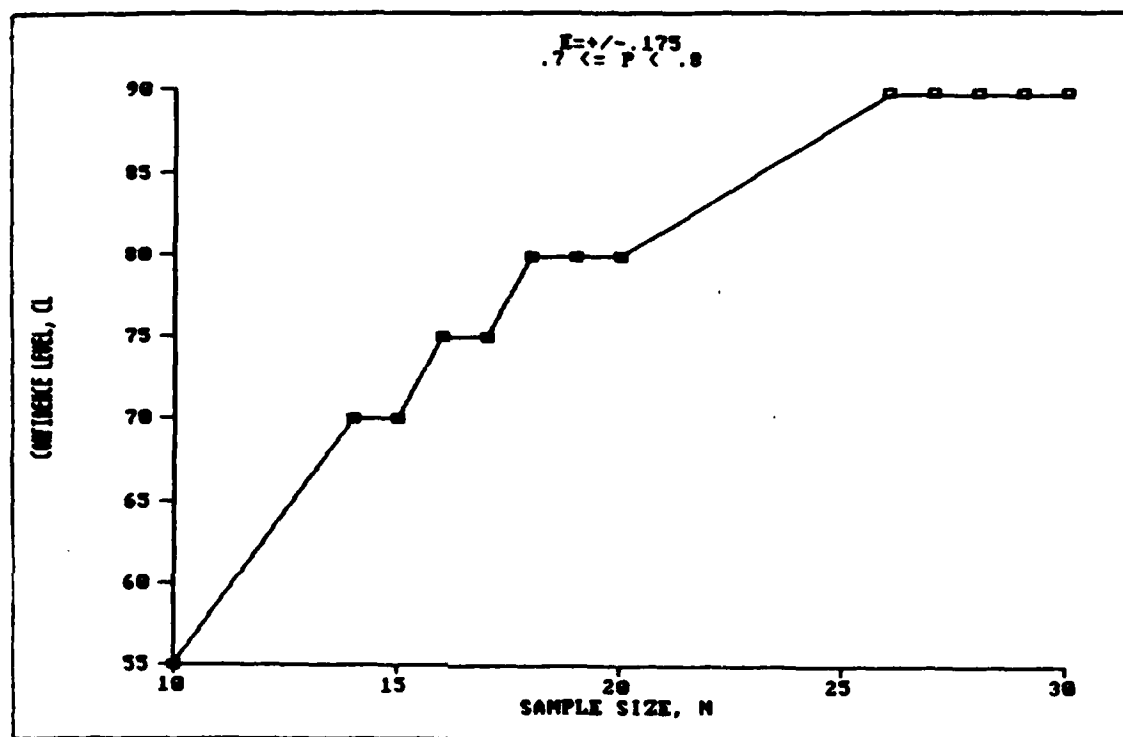
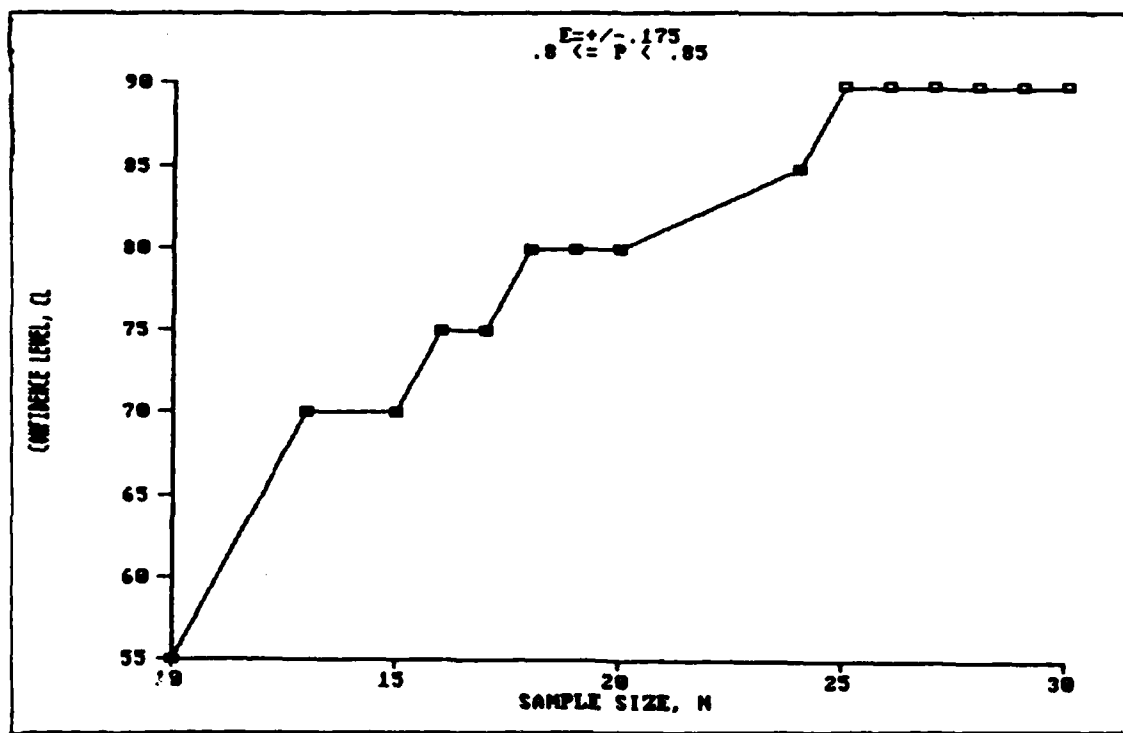












Appendix D: Marx Computer Program and Modified Computer Program

Marx Computer Program :

```

10 REM          EXACT CONFIDENCE BOUNDS FOR PROPORTIONS
20 REM          BEST.BAS v1.01
22 REM          12/08/87

30 REM
40 REM
50 REM          Copyright 1987
60 REM          Donald L. Marx
70 REM          University of Alaska, Anchorage
80 REM          School of Business
90 REM          Anchorage, AK 99508
100 REM         (907) 786-1755

110 REM
120 REM
130 REM
140 REM          DEFINITION OF VARIABLES
150 REM          A(.) - Table of probabilities for standard normal quantiles
160 REM          ALP - Tail probability for search procedure
170 REM          ALPHA - Tail prob. for one- or two-sided confidence interval
180 REM          C - Standard normal quantile to initiate search.
190 REM          CDF - cumulative distribution function for binomial(n,p)
200 REM          CL - confidence level (X).
210 REM          DELTA - Stopping criterion for search procedure.
220 REM          DIFF - Diff. between calculated and specified tail probability
230 REM          DP - first derivative of p wrt alpha at alpha=ALP.
240 REM          D2P - second derivative of P wrt to alpha at alpha=ALP.
250 REM          IX - Temporary index number.
260 REM          ITERX - Stopping criterion for search procedure.
270 REM          JS - interactive response.
280 REM          K - temporary index number.
290 REM          LBO - Lower bound based on std. normal approx.
300 REM          NX - temporary index number.
310 REM          NACCZ - maximum sample size for guaranteed accuracy.
320 REM          PHAT - sample proportion of 'successes'.
330 REM          T1 - intermediate calculation (i = 1,2,3).
340 REM          TX - temporary index number.
350 REM          UBO - upper bound based on std. normal approx.
360 REM          XZ - YX or NX - YX whichever is smaller.
370 REM          P - proportion of 'successes' in population.
380 REM          PDF - probability mass function for binomial(n,p).
390 REM          PI - 3.141592654000003
400 REM          YX - number of 'successes' in sample.
410 REM          Z(.) - table of standard normal quantiles.
420 DIM A(20),Z(20)
430 PRINT CHR$(12)
440 PRINT
450 PRINT
460 PRINT "This program will construct exact confidence"
470 PRINT "bounds for the proportion of 'successes' in a"
480 PRINT "population based on the observation of y"
490 PRINT "'successes' in n independent Bernoulli trials."
500 PRINT
510 GOSUB 1000: REM          Set default values
520 GOSUB 2000: REM          Enter data
530 GOSUB 3000: REM          Compute point estimate
540 IF YX = 0 THEN GOSUB 4000: REM          YX = 0 module

```

```

550 IF YX = NX THEN GOSUB 5000: REM      YX = n module
560 IF YX > 0 AND YX < NX THEN GOSUB 6000
570 PRINT
580 PRINT
590 INPUT 'Do you wish to make another run';JS
600 IF JS = 'y' OR JS = 'Y' THEN GOTO 520
610 SYSTEM
620 REM -----
1000 REM
1010 REM      SUBROUTINE
1020 REM      SET DEFAULT VALUES
1030 REM
1040 LET NACCX = 126
1050 LET DELTA = .00001
1055 LET ITERX = 10
1060 PRINT 'An iterative search procedure is used to'
1070 PRINT 'calculate upper and lower bounds such that'
1080 PRINT 'each calculated tail probability is within'
1090 PRINT USING 's.#### of the specified value. If,':DELTA
1100 PRINT 'however, this accuracy specification is not'
1110 PRINT USING 'reached within ### iterations. the message':ITERX
1120 PRINT '      MAXIMUM ITERATIONS COMPLETED'
1130 PRINT 'is displayed and the search is discontinued.'
1140 PRINT USING 'Using sample sizes greater than ### may pro-':NACCX
1150 PRINT 'duce errors in excess of specified accuracy.'
1160 PRINT
1190 FOR IX = 0 TO 19
1200 READ A(IX),Z(IX)
1210 NEXT IX
1220 DATA .0001,3.719,.0005,3.2905,.001,3.0902,.0025,2.807,.005,2.5758,.01
1221 DATA 2.3263,.02,2.0537,.025,1.96,.05,1.6449,.075,1.4395,.1,1.2816,.125
1222 DATA 1.1503,.15,1.0364,.175,.9346,.2,.8416,.25,.6745,.3,.5244,.35,.3853
1223 DATA .4,.2533,.5,0
1230 REM      The above data are taken from Pearson and Hartley's
1240 REM      'Biometrika Tables for Statisticians', 3rd. ed.,
1250 REM      Tables J and 4. Using their notation, Q and X
1260 REM      are entered in pairs in increasing order of Q.
1270 RETURN
1280 REM -----
2000 REM
2010 REM      SUBROUTINE
2020 REM      ENTER DATA
2030 REM
2040 PRINT: INPUT 'Enter sample size':T1
2050 IF T1 = INT(T1) AND T1 > 0 THEN NX = T1: GOTO 2070
2060 PRINT 'Positive integer required': GOTO 2040
2070 PRINT: INPUT 'Enter number of 'successes':T1
2080 IF T1 = INT(T1) AND T1 <= NX THEN YX = T1: GOTO 2100
2090 PRINT USING 'Positive integer <= ### required.':NX: GOTO 2070
2100 PRINT: INPUT 'Confidence level (X)':CL
2110 IF 99.99 < 100*(1-DELTA) THEN T1 = 99.99 ELSE LET T1 = 100*(1-DELTA)
2120 IF CL > 50 AND CL <= T1 THEN RETURN
2130 PRINT USING 'Number between 50 and ###.## required.':T1
2140 GOTO 2100
2150 REM -----

```

```

3000 REM
3010 REM          SUBROUTINE
3020 REM          COMPUTE POINT ESTIMATE
3030 REM
3040 PHAT = YX/NX
3060 PRINT: PRINT: PRINT
3070 PRINT: PRINT: PRINT
3080 PRINT          POINT ESTIMATE FOR PROPORTIONS
3090 PRINT
3095 PRINT USING 'Using **** 'successes' in *** trials, the point';YX,NX
3100 PRINT 'estimate of the population proportion is ';PHAT
3110 PRINT 'The standard error of the estimate is ';SQR(PHAT*(1-PHAT)/NX)
3120 RETURN
3130 REM -----
4000 REM
4010 REM          SUBROUTINE
4020 REM          YX = 0 MODULE
4030 REM
4040 PRINT
4050 PRINT
4060 PRINT 'Symmetric confidence interval does not exist.'
4070 PRINT
4080 PRINT USING 'The **. ** x upper bound is ';CL;
4090 PRINT 1-(1-CL/100)^(1/NX)
4100 RETURN
4110 REM -----
5000 REM
5010 REM          SUBROUTINE
5020 REM          YX = NX MODULE
5030 REM
5040 PRINT
5050 PRINT
5060 PRINT 'Symmetric confidence interval does not exist.'
5070 PRINT
5080 PRINT USING 'The **. ** x lower bound is ';CL;
5090 PRINT (1-CL/100)^(1/NX)
5100 RETURN
5110 REM -----
6000 REM
6010 REM          SUBROUTINE
6020 REM          0 < YX < NX MODULE
6030 REM
6040 PRINT: PRINT: PRINT
6050 PRINT: PRINT: PRINT
6060 PRINT: PRINT: PRINT
6070 PRINT 'Select an option:'
6080 PRINT
6090 PRINT '1. Symmetric confidence interval'
6100 PRINT '2. Upper bound'
6110 PRINT '3. Lower bound'
6120 INPUT TX
6130 IF TX < 1 GOTO 6000
6140 IF TX > 3 GOTO 6000
6150 LET TX = INT(TX)
6160 PRINT: PRINT: PRINT

```

```

6190 PRINT '          POINT ESTIMATES FOR PROPORTIONS'
6200 PRINT
6210 PRINT USING 'Using **** 'successes' in **** trials, the point';YX,NX
6220 PRINT 'estimate of the population proportion is ';PHAT
6230 PRINT 'The standard error of the estimate is ';SQR(PHAT*(1-PHAT)/NX)
6240 PRINT: PRINT: PRINT
6250 PRINT: PRINT: PRINT
6260 PRINT '          CONFIDENCE BOUNDS FOR PROPORTIONS'
6270 PRINT USING '          (**. **% confidence level)';CL
6280 IF TX = 1 THEN ALPHA = (100-CL)/200 ELSE ALPHA = 1-CL/100
6290 REM
6300 REM          GET INITIAL ESTIMATE FOR P
6310 REM
6320 FOR IX = 1 TO 19
6330 IF A(IX) > ALPHA GOTO 6350
6340 NEXT IX
6350 LET C = Z(IX-1)
6360 LET T1 = (ALPHA-A(IX-1))/(A(IX)-A(IX-1))
6370 LET C = Z(IX-1) + T1*(Z(IX)-Z(IX-1))
6380 LET T1 = 2*NX*PHAT + C*C
6390 LET T2 = C*C + 4*PHAT*(1-PHAT)*NX - 1/NX
6400 LET T3 = 2*(NX + C*C)
6410 LET UBO = (T1 + 1 + C*SQR(T2 + 2 - 4*PHAT))/T3
6420 IF UBO > 1 THEN UBO = 1
6430 LET LBO = (T1 - 1 - C*SQR(T2 - 2 + 4*PHAT))/T3
6440 IF LBO < 0 THEN LET LBO = 0
6450 PRINT
6460 IF TX = 1 OR TX = 3 THEN GOSUB 8000: REM          Lower bound module
6470 PRINT
6480 IF TX = 1 OR TX = 2 THEN GOSUB 7000: REM          Upper bound module
6490 RETURN
6500 REM -----
7000 REM
7010 REM          SUBROUTINE
7020 REM          UPPER BOUND
7030 REM
7040 IF 2*UBO <= 1 THEN LET XZ = YX: ALP = ALPHA: P = UBO
7050 IF 2*UBO > 1 THEN LET XZ = NX - YX - 1: ALP = 1 - ALPHA: P = 1 - UBO
7060 GOSUB 9000: REM          Search for P
7070 IF 2*UBO <= 1 THEN PRINT 'Upper bound =';P
7080 IF 2*UBO > 1 THEN PRINT 'Upper bound =';1-P
7090 RETURN
7100 REM -----
8000 REM
8010 REM          SUBROUTINE
8020 REM          LOWER BOUND
8030 REM
8040 IF 2*LBO <= 1 THEN LET XZ = YX - 1: ALP = 1 - ALPHA: P = LBO
8050 IF 2*LBO > 1 THEN LET XZ = NX - YX: ALP = ALPHA: P = 1 - LBO
8060 GOSUB 9000: REM          Search for P
8070 IF 2*LBO <= 1 THEN PRINT 'Lower bound =';P
8080 IF 2*LBO > 1 THEN PRINT 'Lower bound =';1 - P
8090 RETURN
8100 REM -----
9000 REM

```

```

9010 REM                      SUBROUTINE
9020 REM                      ITERATIVE SEARCH FOR P
9030 REM
9040 LET P0 = P
9050 FOR IX = 1 TO ITERX
9060 LET PDF = (1 - P)NX
9070 IF PDF < 1E-38 THEN GOTO 9250
9080 LET CDF = PDF
9090 FOR KX = 1 TO NX
9100 LET PDF = (NX - KX + 1)*P*PDF/KX/(1 - P)
9110 LET CDF = CDF + PDF
9120 NEXT KX
9130 LET DIFF = ALP - CDF
9140 IF ABS(DIFF) <= DELTA THEN RETURN
9150 LET DP = -(1 - P)/(NX - KX)/PDF
9160 IF DP*DIFF + P <= 0 THEN LET P = P/2: GOTO 9190
9170 IF DP*DIFF + P >= 1 THEN LET P = (1 + P)/2: GOTO 9190
9180 LET P = P + DP*DIFF
9190 NEXT IX
9200 PRINT
9210 PRINT 'MAXIMUM ITERATIONS COMPLETED.'
9220 PRINT 'Change in bound last iteration is';DIFF
9240 RETURN
9250 PRINT 'SAMPLE SIZE TOO LARGE OR SAMPLE PROPORTION TOO'
9260 PRINT 'NEAR 1/2 TO COMPUTE EXACT BINOMIAL DISTRIBUTION.'
9270 LET P = P0
9280 PRINT 'Using the normal approximation.'
9290 RETURN

```

Modified Computer Program:

```

10 REM          EXACT CONFIDENCE BOUNDS FOR PROPORTIONS
12 OPEN "O",#1,"SAMPLES.DAT"
20 REM          BEST.BAS v1.01
22 REM          12/08/87
30 REM
40 REM
50 REM          Copyright 1987
60 REM          Donald L. Marx
70 REM          University of Alaska, Anchorage
80 REM          School of Business
90 REM          Anchorage, AK 99508
100 REM         (907) 786-1755
110 REM
120 REM
130 REM
140 REM         DEFINITION OF VARIABLES
150 REM         A(.) - Table of probabilities for standard normal quantiles
160 REM         ALP - Tail probability for search procedure
170 REM         ALPHA - Tail prob. for one- or two-sided confidence interval
180 REM         C - Standard normal quantile to initiate search.
190 REM         CDF - cumulative distribution function for binomial(n,p)
200 REM         CL - confidence level (%).
210 REM         DELTA - Stopping criterion for search procedure.
220 REM         DIFF - Diff. between calculated and specified tail probability
230 REM         DP - first derivative of p wrt alpha at alpha=ALP.
240 REM         D2P - second derivative of P wrt to alpha at alpha=ALP.
250 REM         IX - Temporary index number.
260 REM         ITERX - Stopping criterion for search procedure.
270 REM         JS - interactive response.
280 REM         K - temporary index number.
290 REM         LBO - Lower bound based on std. normal approx.
300 REM         NX - temporary index number.
310 REM         NACCX - maximum sample size for guaranteed accuracy.
320 REM         PHAT - sample proportion of 'successes'.
330 REM         T1 - intermediate calculation (i = 1,2,3).
340 REM         TX - temporary index number.
350 REM         UBO - upper bound based on std. normal approx.
360 REM         XZ - YX or NX - YX whichever is smaller.
370 REM         P - proportion of 'successes' in population.
380 REM         PDF - probability mass function for binomial(n,p).
390 REM         PI - 3.141592654000005
400 REM         YX - number of 'successes' in sample.
410 REM         Z(.) - table of standard normal quantiles.
420 DIM A(20),Z(20)
430 REM PRINT CHR$(12)
440 FOR NX = 20 TO 30 STEP 2
450 FOR YX = 21 TO 29 STEP 2
460 IF YX <= NX THEN GOTO 470 ELSE GOTO 590
470 FOR CL = 55 TO 95 STEP 3
500 LET IX = 0
510 GOSUB 1000: REM          Set default values
530 GOSUB 3000: REM         Compute point estimate
540 IF YX = 0 THEN GOSUB 4000: REM          YX = 0 module
550 IF YX = NX THEN GOSUB 5000: REM          YX = n module
560 IF YX > 0 AND YX < NX THEN GOSUB 6000

```

```

570 REM WRITE #1,NX,YX,CL
580 NEXT CL
590 NEXT YX
600 NEXT NX
605 CLOSE #1
610 SYSTEM
620 REM -----
1000 REM
1010 REM          SUBROUTINE
1020 REM          SET DEFAULT VALUES
1030 REM
1040 LET NACCX = 126
1050 LET DELTA = .00001
1055 LET ITERX = 10
1180 REM
1181 A(1) = .0001:A(2) = .0005:A(3) = .001:A(4) = .0025
1182 Z(1) = 3.719:Z(2) = 3.2905:Z(3) = 3.0902:Z(4) = 2.807
1183 A(5) = .005:A(6) = .01:A(7) = .02:A(8) = .025
1184 Z(5) = 2.5758:Z(6) = 2.3263:Z(7) = 2.0537:Z(8) = 1.96
1185 A(9) = .05:A(10) = .075:A(11) = .1:A(12) = .125
1186 Z(9) = 1.6449:Z(10) = 1.4395:Z(11) = 1.2816:Z(12) = 1.1503
1187 A(13) = .15:A(14) = .175:A(15) = .2:A(16) = .25
1188 Z(13) = 1.0364:Z(14) = .9346:Z(15) = .8416:Z(16) = .6745
1189 A(17) = .3:A(18) = .35:A(19) = .4:A(20) = .5
1190 Z(17) = .5244:Z(18) = .3853:Z(19) = .2533:Z(20) = 0
1191 REM
1221 REM 2.3263,.02,2.0537,.025,1.96,.05,1.6449,.075,1.4395,.1,1.2816,.125
1222 REM 1.1503,.15,1.0364,.175,.9346,.2,.8416,.25,.6745,.3,.5244,.35,.3853
1223 REM .4,.2533,.5,0
1230 REM          The above data are taken from Pearson and Hartley's
1240 REM          'Biometrika Tables for Statisticians', 3rd. ed.,
1250 REM          Tables 3 and 4. Using their notation, Q and X
1260 REM          are entered in pairs in increasing order of Q.
1265 REM
1270 RETURN
1280 REM -----
2150 REM -----
3000 REM
3010 REM          SUBROUTINE
3020 REM          COMPUTE POINT ESTIMATE
3030 REM
3040 PHAT = YX/NX
3060 REM PRINT: PRINT: PRINT
3070 REM PRINT: PRINT: PRINT
3080 REM PRINT '          POINT ESTIMATE FOR PROPORTIONS'
3090 REM PRINT
3095 REM PRINT USING 'Using **** 'successes' in **** trials, the point';YX,NX
3100 REM PRINT 'estimate of the population proportion is ';PHAT
3110 REM PRINT 'The standard error of the estimate is ';SQR(PHAT*(1-PHAT)/NX)
3120 RETURN
3130 REM -----
4000 REM
4010 REM          SUBROUTINE
4020 REM          YX = 0 MODULE
4030 REM

```

```

4040 REM PRINT
4050 REM PRINT
4060 REM PRINT 'Symmetric confidence interval does not exist.'
4070 REM PRINT
4080 REM PRINT USING 'The **. ** % upper bound is ';CL;
4090 REM PRINT 1-(1-CL/100)^(1/NX)
4095 WRITE #1,1-(1-CL/100)^(1/NX)
4100 RETURN
4110 REM -----
5000 REM
5010 REM          SUBROUTINE
5020 REM          YX = NX MODULE
5030 REM
5040 REM PRINT
5050 REM PRINT
5060 REM PRINT 'Symmetric confidence interval does not exist.'
5070 REM PRINT
5080 REM PRINT USING 'The **. ** % lower bound is ';CL;
5090 REM PRINT (1-CL/100)^(1/NX)
5095 WRITE #1,(1-CL/100)^(1/NX),NX,YX,CL
5100 RETURN
5110 REM -----
6000 REM
6010 REM          SUBROUTINE
6020 REM          0 < YX < NX MODULE
6030 REM
6040 REM: PRINT: PRINT
6050 REM: PRINT: PRINT
6060 REM: PRINT: PRINT
6070 REM PRINT 'Select an option:'
6080 REM PRINT
6090 REM PRINT '1. Symmetric confidence interval'
6100 REM PRINT '2. Upper bound'
6110 REM PRINT '3. Lower bound'
6120 LET TX=1
6130 IF TX < 1 GOTO 6000
6140 IF TX > 3 GOTO 6000
6150 LET TX = INT(TX)
6160 REM PRINT: PRINT: PRINT
6190 REM PRINT '          POINT ESTIMATES FOR PROPORTIONS'
6200 REM PRINT
6210 REM PRINT USING 'Using **** 'successes' in **** trials, the point';YX,NX
6220 REM PRINT 'estimate of the population proportion is ';PHAT
6230 REM PRINT 'The standard error of the estimate is ';SQR(PHAT*(1-PHAT)/NX)
6240 REM PRINT: PRINT: PRINT
6250 REM PRINT: PRINT: PRINT
6260 REM PRINT '          CONFIDENCE BOUNDS FOR PROPORTIONS'
6270 REM PRINT USING '          (**. **% confidence level)';CL
6280 IF TX = 1 THEN ALPHA = (100-CL)/200 ELSE ALPHA = 1-CL/100
6290 REM
6300 REM          GET INITIAL ESTIMATE FOR P
6310 REM
6320 FOR IX = 1 TO 10
6330 IF A(IX) > ALPHA GOTO 6350
6340 NEXT IX

```

```

6350 LET C = Z(IX-1)
6360 LET T1 = (ALPHA-A(IX-1))/(A(IX)-A(IX-1))
6370 LET C = Z(IX-1) + T1*(Z(IX)-Z(IX-1))
6380 LET T1 = 2*NZ*PHAT + C*C
6390 LET T2 = C*C + 4*PHAT*(1-PHAT)*NZ - 1/NZ
6400 LET T3 = 2*(NZ + C*C)
6410 LET UBO = (T1 + 1 + C*SQR(T2 + 2 - 4*PHAT))/T3
6420 IF UBO > 1 THEN UBO = 1
6430 LET LBO = (T1 - 1 - C*SQR(T2 - 2 + 4*PHAT))/T3
6440 IF LBO < 0 THEN LET LBO = 0
6450 PRINT
6460 IF TX = 1 OR TX = 3 THEN GOSUB 8000: REM          Lower bound module
6470 PRINT
6480 IF TX = 1 OR TX = 2 THEN GOSUB 7000: REM          Upper bound module
6490 RETURN
6500 REM -----
7000 REM
7010 REM          SUBROUTINE
7020 REM          UPPER BOUND
7030 REM
7040 IF 2*UBO <= 1 THEN LET XZ = YZ: ALP = ALPHA: P = UBO
7050 IF 2*UBO > 1 THEN LET XZ = NZ - YZ - 1: ALP = 1 - ALPHA: P = 1 - UBO
7060 GOSUB 9000: REM          Search for P
7070 IF 2*UBO <= 1 THEN WRITE #1,P
7080 IF 2*UBO > 1 THEN WRITE #1,1-P
7090 RETURN
7100 REM -----
8000 REM
8010 REM          SUBROUTINE
8020 REM          LOWER BOUND
8030 REM
8040 IF 2*LBO <= 1 THEN LET XZ = YZ - 1: ALP = 1 - ALPHA: P = LBO
8050 IF 2*LBO > 1 THEN LET XZ = NZ - YZ: ALP = ALPHA: P = 1 - LBO
8060 GOSUB 9000: REM          Search for P
8070 IF 2*LBO <= 1 THEN WRITE #1,P,NZ,YZ,CL
8080 IF 2*LBO > 1 THEN WRITE #1,1 - P,NZ,YZ,CL
8090 RETURN
8100 REM -----
9000 REM
9010 REM          SUBROUTINE
9020 REM          ITERATIVE SEARCH FOR P
9030 REM
9040 LET P0 = P
9050 FOR IX = 1 TO ITERX
9060 LET PDF = (1 - P)^NZ
9070 IF PDF < 1E-38 THEN 9250
9080 LET CDF = PDF
9090 FOR KX = 1 TO XZ
9100 LET PDF = (NZ - KX + 1)*P*PDF/KX/(1 - P)
9110 LET CDF = CDF + PDF
9120 NEXT KX
9130 LET DIFF = ALP - CDF
9140 IF ABS(DIFF) <= DELTA THEN RETURN
9150 LET DP = -(1 - P)/(NZ - XZ)/PDF
9160 IF DP*DIFF + P <= 0 THEN LET P = P/2: GOTO 9100

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9170 IF DP=DIFF + P >= 1 THEN LET P = (1 + P)/2: GOTO 9190
9180 LET P = P + DP=DIFF
9190 NEXT IX
9200 PRINT
9210 PRINT 'MAXIMUM ITERATIONS COMPLETED.'
9220 PRINT 'Change in bound last iteration is':DIFF
9240 RETURN
9250 PRINT 'SAMPLE SIZE TOO LARGE OR SAMPLE PROPORTION TOO'
9260 PRINT 'NEAR 1/2 TO COMPUTE EXACT BINOMIAL DISTRIBUTION.'
9270 LET P = P0
9280 PRINT 'Using the normal approximation.'
9290 RETURN

```

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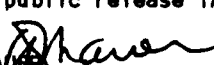
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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GSM/LSM/88S-22			7a. NAME OF MONITORING ORGANIZATION		
6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics	6b. OFFICE SYMBOL (If applicable) AFIT/LSM	7b. ADDRESS (City, State, and ZIP Code)			
6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright Patterson AFB OH 45433-6583		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	10. SOURCE OF FUNDING NUMBERS			
8c. ADDRESS (City, State, and ZIP Code)		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) DEVELOPING CRITERIA FOR SAMPLE SIZES IN JET ENGINE ANALYTICAL COMPONENT INSPECTIONS AND THE ASSOCIATED CONFIDENCE LEVELS					
12. PERSONAL AUTHOR(S) Tami S. Richards, B.S., Capt, USAF					
13a. TYPE OF REPORT MS Thesis	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) 1988 September		15. PAGE COUNT 131	
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP			
21	05		Management and Planning Control Logistics Inspection Jet Engines		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>Thesis Advisor: Phillip E. Miller, Major, USAF Graduate Programs Director School of Systems and Logistics</p> <p>Approved for public release IAW AFR 190-1.</p> <p>WILLIAM A. MAUSER  17 Oct 88 Associate Dean School of Systems and Logistics Air Force Institute of Technology (AU) Wright-Patterson AFB OH 45433</p>					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL Phillip E. Miller, Grad. Programs Dir.			22b. TELEPHONE (Include Area Code) (513)255-4437		22c. OFFICE SYMBOL LSG

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The purpose of this study was to provide managers of USAF jet engine programs with a model to help determine an appropriate sample size of engines/components to be inspected in a Lead-The-Force/Analytical Component Inspection (LTF/ACI) program. The major purpose of a LTF/ACI program is to identify problems and failure trends in engines/components before the problems are experienced by the majority of the fleet. The concept behind the LTF/ACI program is that a sample of engines with accelerated operating hours can represent the future status of the entire fleet. Initial inspection intervals for the fleet are set low and extended as the LTF/ACI engines/components pass inspection criteria.

The study has two objectives: (1) to determine what sample size of components is required to reach some specific level of confidence that the fleet inspection interval can be increased; (2) to determine the risk or decrease in confidence that is associated with a less-than-optimum sample size.

Small sample binomial statistics were used for the analysis due to the small number of engines/components usually inspected in a LTF/ACI program and the pass/fail nature of the inspection plan.

The study found that the increase (decrease) in confidence attained by varying the sample size of engines/components slightly is significant enough to warrant careful consideration by managers attempting to balance cost, logistical, and engineering constraints. The study provides data tables and graphs presenting the required sample sizes to ensure varying confidence levels for varying levels of an acceptable number of components/engines that pass inspection within specified error limits.

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